UNITED STATES DEPARTMENT OF AGRICULTURE

FOREST SERVICE

MOTOR GRADER TEST

Report of

Rome Grader - Model 402

San Bernardino National Forest

January 23 - March 15, 1950

by

Division of Engineering

and

Arcadia Equipment Development Center

Region 5 - Forest Service

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ABSTRACT

This report covers the inspection and testing of the heavy class Rome 402 Grader, to determine its ability to perform ordinary maintenance and constrution encountered in Forest Service work.

The results obtained indicate that the Rome 402, in its present form as submitted, is not capable of doing the required job, because of basic design.

The tests bring out that failure of the machine was due principally to lack of -

1. Blade maneuverability.

2. Blade stability.

3. Consideration to operator fatigue.

4. Quality in workmanship.

INTRODUCTION

The grader test described in this report is the result of an effort on the part of the Division of Engineering to determine the adequacy of commercial units offered on bid invitation to perform in accordance with the rigid requirements of the field. This report is on one unit of the Motor Grader Test Project conducted on the San Bernardino National Forest, January 23 to March 15, 1950.

Originally scheduled for two units, the project was expanded at the request of manufacturers to include five companies and five graders ranging from the 22,000 lb. to the 27,000 lb. classes.

This is one of the individual reports prepared for each of the five graders tested. The results of the entire test project are summarized in a composite In-Service, Confidential report which includes a more general analysis and encompasses a wider scope in objectives.

The actual field testing of the graders was divided into two major sections (1) physical characteristics, and (2) field performance.

The first section, referred to as the "flat land" test, consists essentially of observations as to physical design characteristics. This includes such items as clearances, blade maneuverability, turning radius, observations on operational features, visibility, operation of controls, and other such data as would be apparent from a detailed inspection of the machine.

The second section consists of a series of field tests designed to simulate the various field operations normally encountered in routine truck trail maintenance on the National Forests. Such operations as bank sloping, drainage dip construction, three-pass road maintenance, finish grading and several others are included to establish the field operation characteristics of the grader tested.

Every effort has been made to assure comparable test conditions for all graders. Standard procedures were devised, quantities and distances measured, and particular attention paid to soil conditions. Operators were given an instruction period prior to test and allowed to use the machine until such time as they were considered competent by company representatives or, in their absence, road foremen skilled in the use of patrol graders. Company representatives were encouraged to request re-runs where they felt conditions adverse or their machine capable of better performance.

ROME GRADER

The grader furnished for test was a Model 402 Rome, manufactured by the Rome Grader Division of the Union Fork and Hoe Company of Rome, New York. The unit was rated as a heavy class, tandem drive, with leaning wheels and full revolving circle, and was equipped with cab, scarifier and oversized tires on the front wheels. The controls were hydraulic, brakes were provided on all tandem wheels and the grader was powered with an electric start. 113 HP high torque Hercules Diesel Engine.

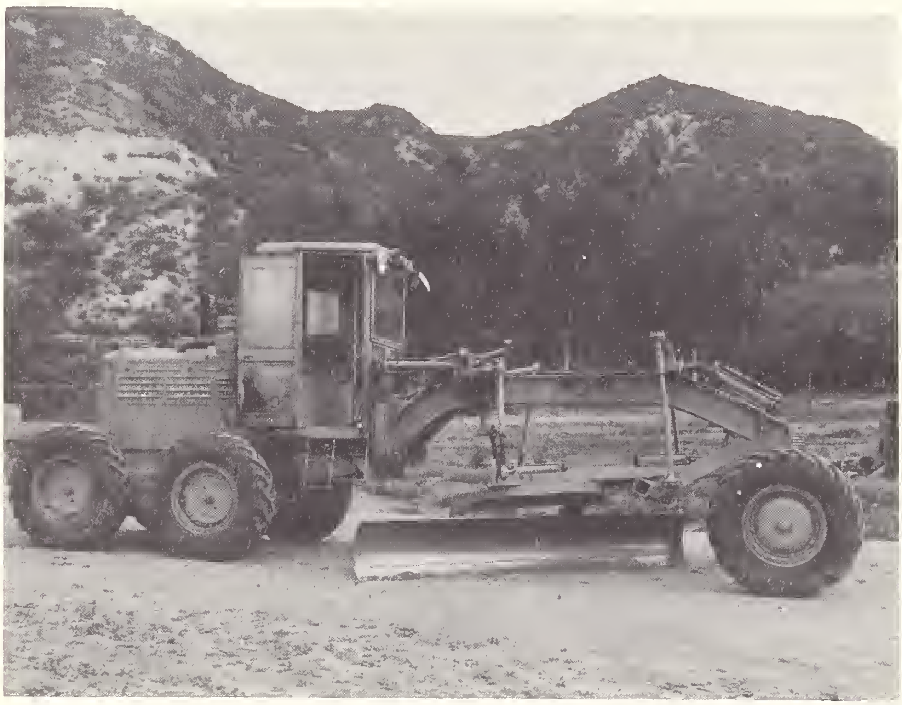


Fig. 1 - Rome Grader, Model 402

DESCRIPTION OF TESTS

Section 1

Flat Land Tests

The first phase of the "flat land" test was the obtaining of data covering weights, dimensions, clearances, engine data, fuel requirements, and the other facts concerning the machine as usually given on manufacturers' specification sheets. Data taken from specification sheets and from the inspections are tabulated for comparison and shown as columns 1 and 2 of Table 1, Test Results Section of the report. In most cases the data agreed with that of the manufacturer but in a few instances notable variations were obtained.

The second phase of the "flat Land" tests consisted of an appraisal of the other physical characteristics of the machine as applied to its various functions. The following tests were performed:

I. BLADE OPERATION

The purpose of this test was to determine the maneuverability of the blade and time required for movement from one position to another.

Equipment used consisted of protractor, tape, plumb bob, stop watch, straight edge, still and movie cameras.

The machine was set on a flat concrete slab. Three reference lines were established; one at the machine fore and aft center line; and one on each side of center, running from the inside of the front tires to the inside of the rear tires. All measurements taken were from these reference lines. Center position of the blade was established as that condition at which, with the blade touching the slab, the blade and circle were centered with the machine. Normal position of the blade was established as that position of the blade in which the machine could operate most advantageously with no change in lift arms or linkage. One cycle of blade circle operation was defined as 360° in the case of machines with full revolving blade, or in case of machines not full revolving the maximum degrees of turn of the blade between obstructions.

A. Operation of Circle. Measurements of time and angle of cycle were taken. Observations were made regarding possibility of damage to parts of the machine by operation of the blade.

B. Locking Devices. Observations regarding the presence or absence of circle locking devices, location, and whether or not they could be considered positive were recorded.

C. Bank Sloping Positions. Starting from centered and normal operating position, the blade was moved to maximum bank sloping angle without moldboard shift. Height of blade tip above ground, bank slope angle, position of heel of blade on ground with respect to the tire reference line, and time to shift to this position were recorded.

The moldboard was then shifted for maximum reach and the blade was set at $1\frac{1}{2}$:1, 1:1, 3/4:1, $\frac{1}{2}$:1 and 1/4:1 bank sloping positions. Height of tip of the blade above ground and position of heel of the blade with respect to the tire reference line were recorded. The time required to shift from blade centered, normal operating position to the maximum bank sloping angle was recorded. Still pictures of each bank slope position were taken.

D. Side Shift. The distance the blade could be moved to right and left of centered position, with and without manual moldboard shifting, was measured. The time required for each operation was also recorded. In all cases distances were measured with the cutting edge of the blade resting on the concrete slab. The crew to shift the moldboard manually was limited to the operator and one helper.

E. Blade Lift. With linkage set for normal operation position, measurements were made and time recorded for movement of the blade from ground level to maximum lift position, and also maximum depth below ground, using a pit for this purpose. The number of holes on lift links and the distance of possible adjustment was recorded.

Starting with blade and circle in center position and at right angles to center line of machine the maximum blade lift angle, both right and left, was measured. Links were adjusted as necessary but the blade was not rotated on the circle for this operation.

The height of the lowest point of the circle with the blade at ground level was measured.

F. Blade Reverse. Ability to reverse the blade was recorded. This test concicted of setting the blade at 45° for casting material to the right, then turning blade for backing up, so as to continue casting material in the same direction.

G. Pitch Positions. Information obtained on pitch positions was as follows - number of notches, total adjustment distances and the degrees from the vertical both plus (top ahead of bottom), and minus (top behind bottom.)

H. Visibility. With the blade centered and at 45°, in both right and left positions, visibility of blade and front wheels was appraised from still photos taken from normal sitting positions showing view to right, left, and straight ahead. This procedure was repeated for visibility from a standing position.

Rear view visibility was also noted, with still pictures recording actual views.

II. WHEEL LEAN

The purpose of the test was to determine the degree to which the wheels could be leaned for turning and for resistance to side thrust in operation.

The degrees of lean, both left and right, were recorded, and still shots were taken showing angle as indicated by large protractor.

III. GRADER GROUND CLEARANCE

The purpose was to determine ability of the grader to clear windrows, rock and obstackes which might be encountered either in forward or reverse operation.

With wheels in a vertical position measurements were taken between lowest projections and the ground, behind the blade, and ahead of blade, the latter being limited to 8 inches on either side of center of the front axle. Particular attention was paid to the possibility of damage to steering geometry if it was the lowest projection.

With wheels at maximum lean, measurements were taken in the same manner.

IV. WIDTH OF FRONT TREAD

To determine tread width of graders equipped with oversize tires in front, measurements were taken from center to center of tires, at point of ground contact.

V. SERVICING REQUIREMENTS.

The object of these observations was to determine the time consumed and materials necessary in servicing the equipment.

The number of grease fittings needing daily and weekly service were counted, and time for each service was recorded by equipment service men. Also recorded was the personnel necessary to do a grease job, lubricants and fuel used and types recommended by the manufacturers.

VI. TIRES AND RIMS

To determine adequacy and safety of this equipment, data were recorded regarding ply, size, number, and manufacturer of tires; type of rim and rim association number. At the end of the test, cuts, breaks and wear were recorded, giving reasons when possible. Still pictures were taken to show condition of tires.

VII. TANK CAPACITY

The purpose of this test was to determine ability of the grader to operate for one 8-hour shift with out requiring additional fuel.

Information recorded included factory specification on consumption, factory specification on tank capacity, hourmeter check, amount of fuel supplied, and whether or not eight hours operation was obtained from a full tank.

VIII. REMOVAL OF WINDOWS, DOORS AND CAB

The object was to determine the ease with which doors, windows (windshield) and cab could be removed.

The test consisted of determining if windows, doors and cab were designed for removal, and estimating the time necessary for each operation. The major portion of data were obtained from Forest Service shop personnel and manufacturers.

IX. LIGHTS

The purpose of this test was to determine the adequacy of lights for night operation and travel.

Intensity of the lights was measured by a Weston meter at a distance of three feet. The source of electricity; whether generator, battery or magneto, was recorded. The location of lights, provision for adjustment, and adequacy of protection were noted.

X. ENGINE STARTING

The purpose of these observations was to determine the ability of the engine to start under field conditions.

Time for at least four different starts was determined by a stop watch. Temperature, humidity, whether the engine was hot or cold, type of starting and factory recommended sequence were recorded.

XI. OPERATION OF CONTROLS

The purpose of this test was to determine the adequacy of grader controls.

Information obtained included accessibility, response, ability to vary speed of control action, operation of any two controls at one time, and ease of gear shifting.

XII. TURNING RADIUS

It was desired (1) to determine the minimum circle in which the grader could turn, both right and left, and the road width necessary to do so, and (2) to determine the ability of the grader to turn by backing around in confined areas.

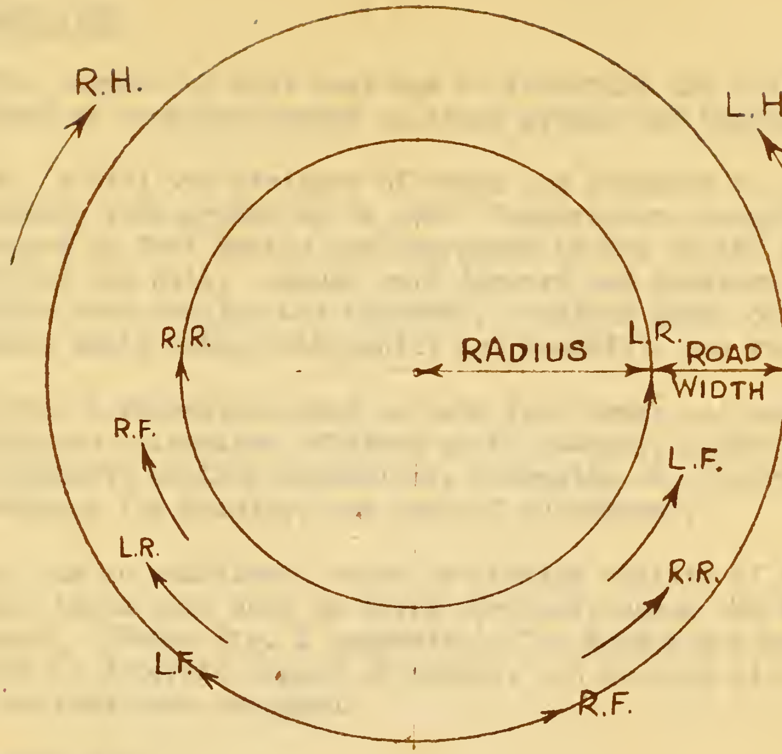
(1) The grader was turned to maximum, and driven to complete a 360° circle, in both right and left direction. The average diameter across the inside tracks was determined by a series of cross-diameter measurements from which the radii were computed.

A second set of measurements was taken across the tracks made in the turning process, and the average taken as the road width necessary for the minimum turn. (Refer to Fig. 2 for sketch.)

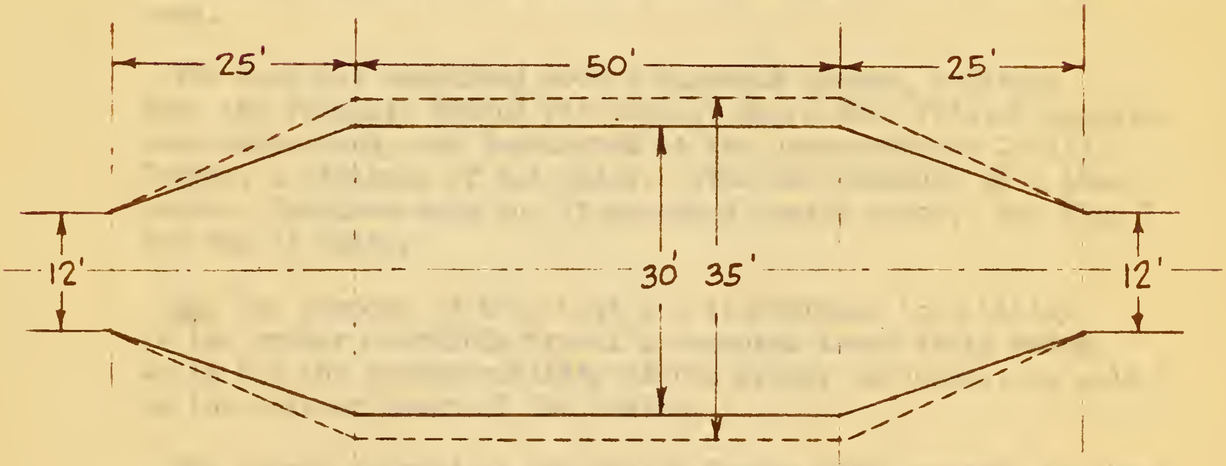
(2) A test area, simulating a turnout on a mountain road, was sketched on a paved area with chalk. The road width approach was 12 feet, tapering to 30 feet at a distance of 25 feet. The 30-foot section extended for a distance of 50 feet.

Operators were allowed to practice on the site so that only maneuverability of the machine was reflected in the test.

The object was to enter the area, turn around with the minimum number of backups, and drive out, keeping within perpendicular limits as designated by the sketched lines. A second set of lines was drawn with a 12-foot road and 35-foot turnout. Separate tests were conducted and results recorded for the 30-foot and the 35-foot width sections. (Refer to Fig. 2 for sketch.)

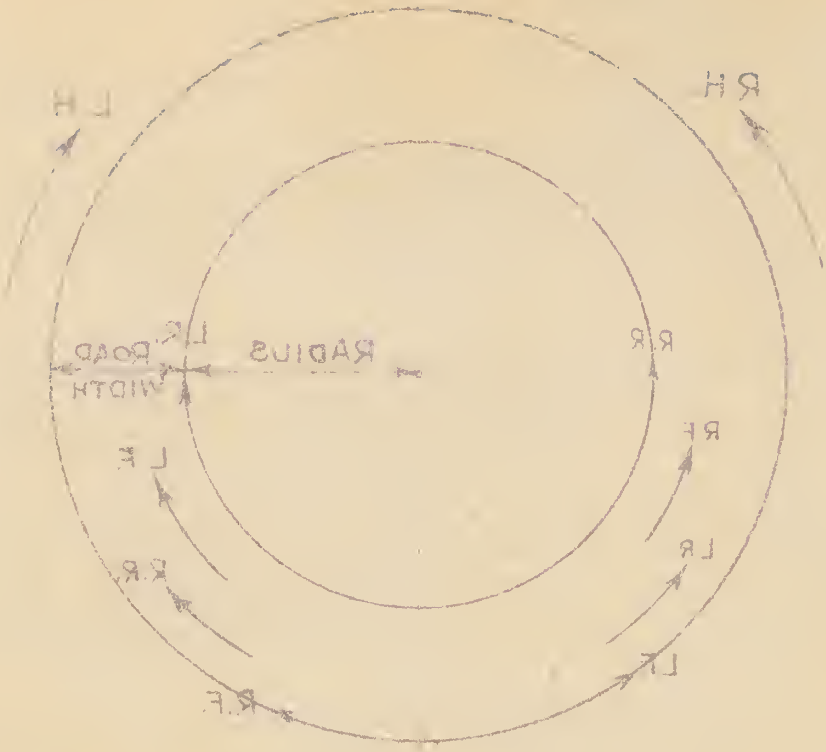


TURNING RADIUS TEST

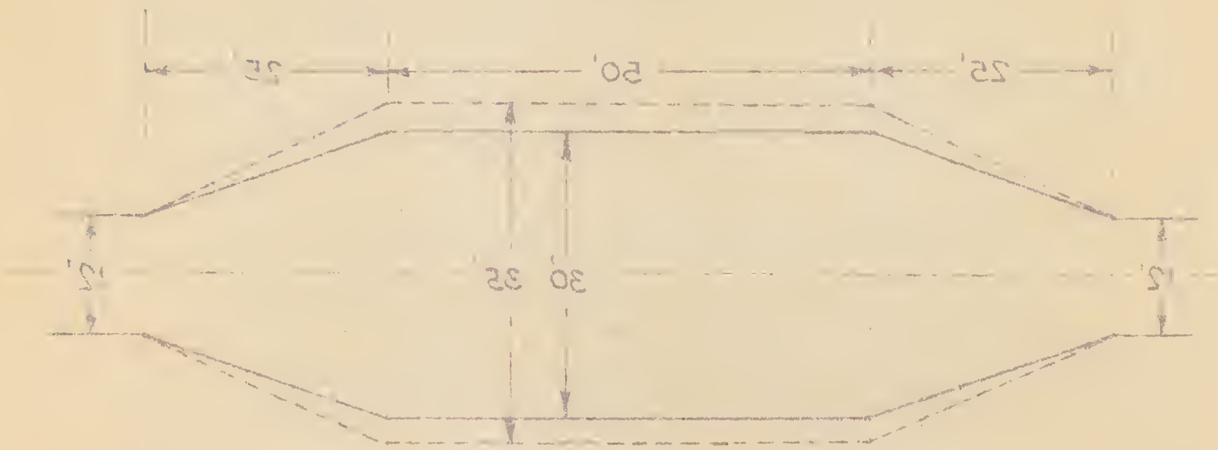


TURN AROUND TEST

FIG. 2



TURNING RADIUS TEST



TURN AROUND TEST

Fig. 2

XIII. BRAKE TEST

The purpose of this test was to determine the ability of the brakes to stop the grader on steep grades and highways.

(a) A hill was stripped of brush and prepared to a compact surface, with grades up to 49%. Graders were required to be stopped by foot brakes and emergency brakes on the steepest part of the hill. Actual roll forward and backward after brakes were applied was measured. Maximum grade on which brakes would hold, both uphill and downhill, was recorded.

Further information noted on both foot brake and parking brake was - location of drums as to 2-wheel, 4-wheel or driveshaft; whether mechanical, hydraulic or electric; provision for holding, and ease of adjustment.

(b) As an additional check on braking ability of the grader, brake tests were made on level pavement, using the AAA brake tester, (Refer Fig. 1 Appendix.) The grader was paced by a car to determine speed of travel, and braking distances for three runs were averaged.

XIV. WALKING TEST

This test was divided into two parts, the first conducted on a paved highway and the second on a truck trail.

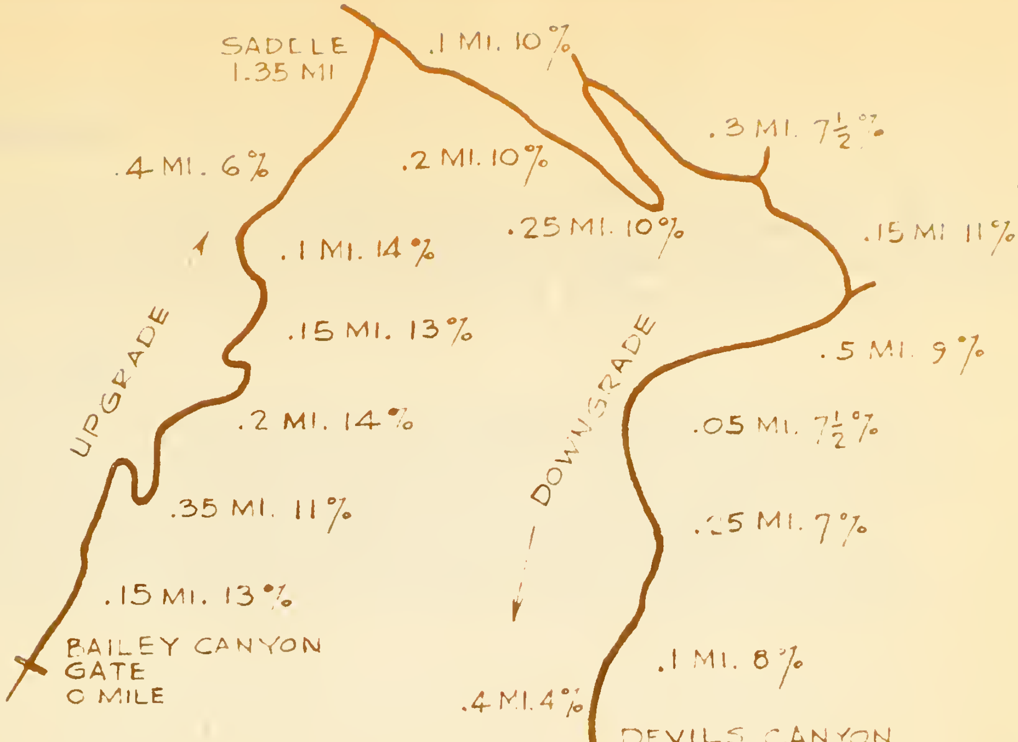
#1. The object in conducting this test was to determine the speed with which the grader could safely travel the highways.

The test was conducted over a measured course, starting from the Triangle Gravel Pit scales, where the official weights were determined, and terminated at the campground at Devil's Canyon, a distance of 6.1 miles. Time was recorded by a stop watch. Machines were run at governed engine speed. See Fig. 3 for map of route.

#2. The purpose of this test was to determine the ability of the grader to safely travel a measured truck trail which would tax the maneuverability of the grader on curves, as well as the maximum power of the engine.

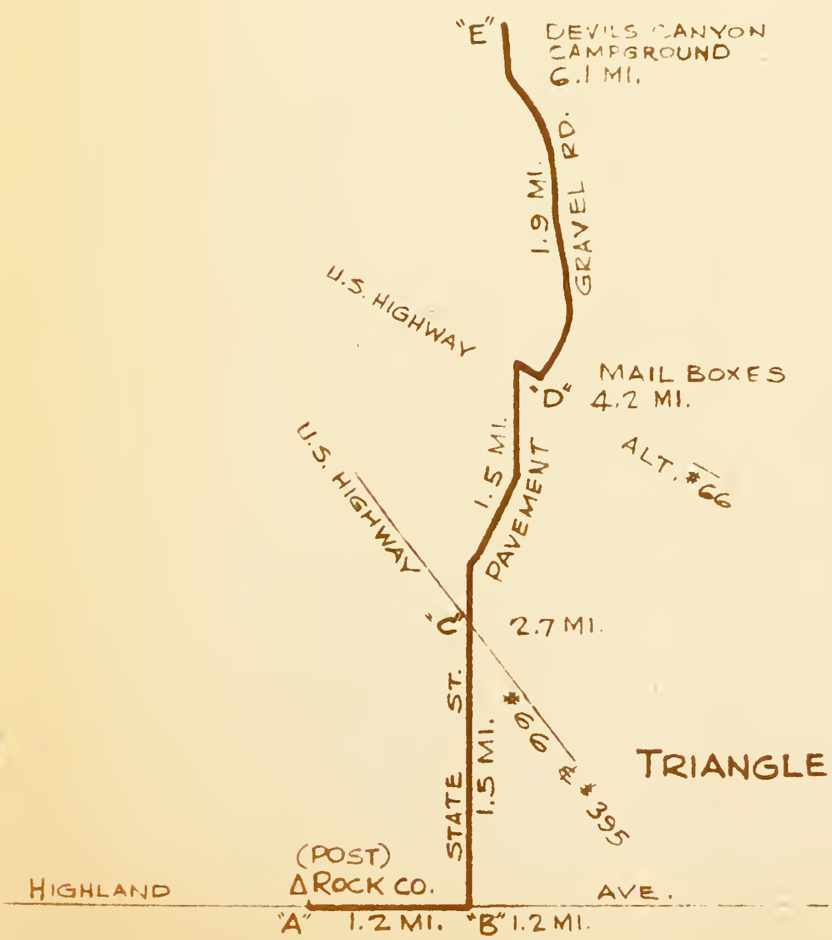
The course started at the Bailey Canyon gate, upgrade to the saddle at the junction of Devil's Canyon truck trail, thence downgrade to Devil's Canyon gate, a distance of 3.65 miles.

Data recorded were time for uphill and downhill trips, grades, and road condition. See Fig. 3 for map of route.



TOTAL MILES 3.65
AVERAGE GRADE 10.36%
1.35 MILES UPGRADE (AV. 11.83%
2.30 MILES DOWNGRADE (AV. 8.89%
1 CURVE LESS THAN 35' RADIUS

BAILEY CANYON WALKING TEST - TRIAL 2



TRIANGLE ROCK TO DEVILS CANYON
SPEED TEST
TRIAL 1

FIG. 3

XV. BREAKDOWNS

While not in the form of a test, an informational list was set up as follows: breakdowns, description of breakdowns, photographic record of each, cause (whether design weakness or accident), facilities to repair, availability of parts, and time lost.

XVI. FINAL CHECK

After the grader had been put through the field tests of Section 2, it was returned to the "flat land" slab, thoroughly cleaned and carefully examined for all cracks, breaks and bends which were not evident as definite breakdowns. Each defect was described and photographed for permanent record. Pictures were taken of the tires to record wear and injuries.

DESCRIPTION OF TESTS

Section 2

Field Test

Field performance tests were as follows:

I. SLIDE REMOVAL

The purpose of the test was to observe the ability of graders to surmount obstacles, such as slides commonly encountered in road maintenance.

Slides occur frequently on roads in steep terrain. If the motor patrol can handle the occasional slide and thus save importing a bulldozer, a considerable saving will result.

A slide of designed shape comprising approximately 125 cubic yards was built by a tractor, avoiding compaction of material as much as possible. Dirt was allowed to accumulate on the downgrade (or approach) side at its natural angle of repose, which was approximately 70%. Boundaries were established by means of stakes simulating a perpendicular bank beyond which a wheel under power was not permitted. Refer to Fig. 4.

Fig. 4. Test Slide

The test machine was required to climb over the slide in order to be in a position to attack the dirt removal task on a downhill basis.

Test conditions were recorded by still shots and progress during the test by movies. Information recorded consisted of - size of slide and time required to climb over, operator sequence and method of attack.

Since more than one machine was tested at this site, after the machine surmounted the slide, no further dirt was removed. The slide was then reconstructed to original size and shape.

II. IN-CURVE

The purpose of the test was to measure the ability of the grader to maneuver on a short radius in-curve.

Conditions of the test: The situation simulated was the wash-out on a canyon crossing, the outer portion of the road being completely gone and the inner portion defined by vertical walls. It was required that the grader was required to travel the curve, using the minimum road width. See Fig. 5 for details and sketch of test layout.

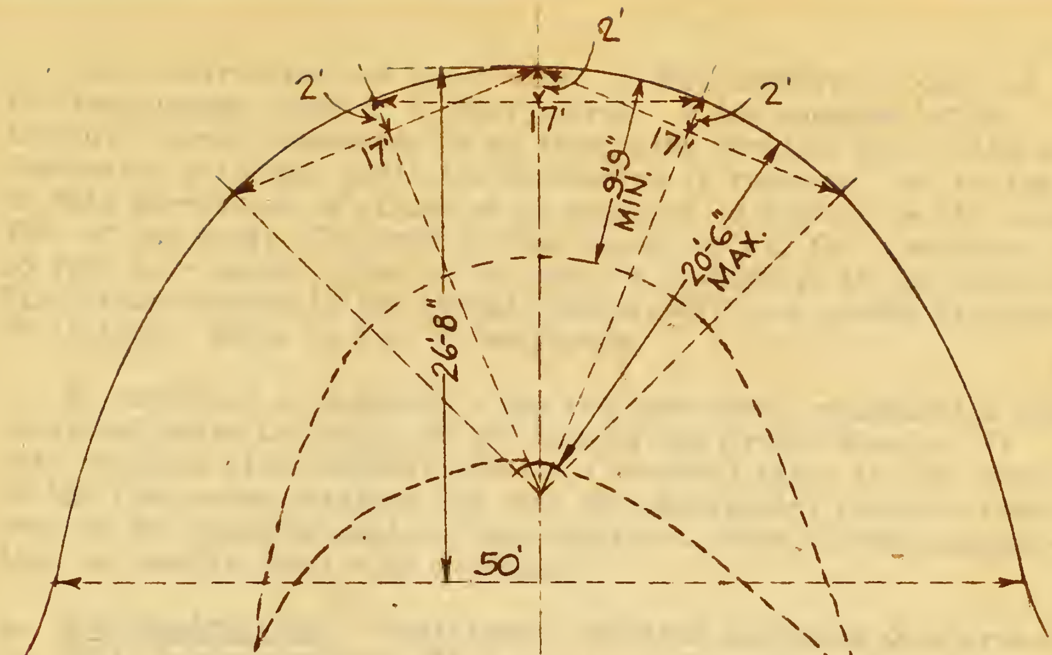
This condition results frequently after severe storms in rugged country. Ability of a particular machine to handle these situations would save much expense in importing a bull dozer for the operation.

Performance was recorded by use of movies and still pictures. The maximum width of road needed as measured from the inside tire track to the simulated perpendicular wall was recorded.

Since ability of operator affects the time required, re-runs were allowed if operator thought he could improve the performance. Regardless of time consumed, operator ability was evaluated in an attempt to determine machine performance, analyzing reasons for such.

III. GRADING OF DIPS

The life and useability of a road depends to a considerable extent upon the proper functioning of the drainage system. Grading of dips is one of the most important operations of a grader on roads where intercepting drainage dips are used.



INCURVE

SIMULATED CONDITION

FIG. 5

The construction and maintenance of dips involves several of the functioning parts of a motor patrol. A dip consists of an involute curve, descending on an increasing vertical curve with an increasing outslope, until the depression if reached. The bottom of this depression is placed at an angle of 45 degrees to the center line of the road. The profile then rises rapidly for a distance of 15 feet to a summit, also at an angle of 45 degrees to the road center line, then returns to the normal road profile in a second distance of 15 feet. Refer to Fig. 6 for sketch.

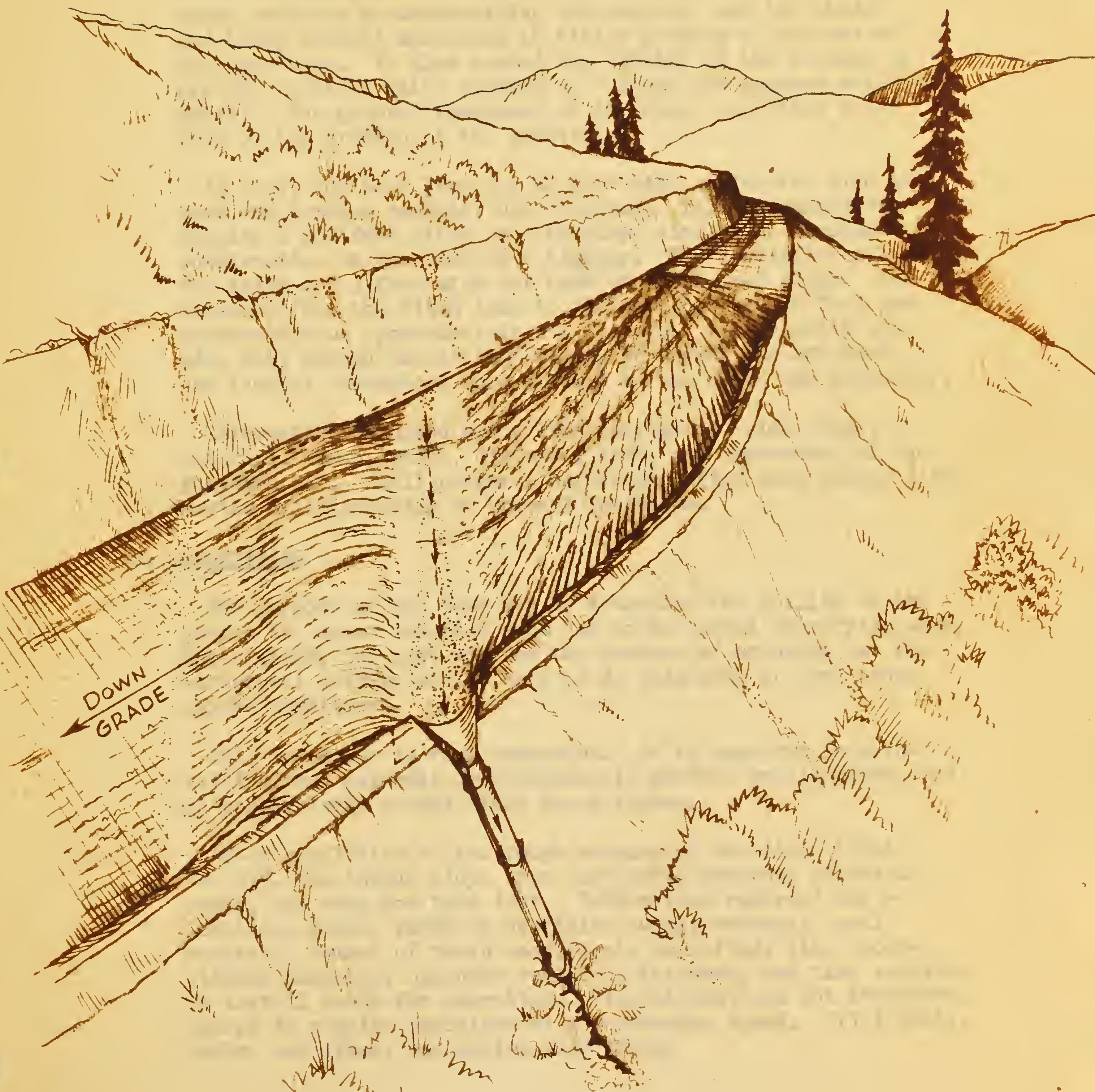
To construct or maintain a dip requires blade manipulation both above and below the plane of the base of the grader wheels. It also requires blade manipulation in a vertical plane to take care of the increasing outslope and also in a horizontal plane to take care of the changing angle of the outslope. This second manipulation is usually handled by steering.

A. <u>New Construction.</u> Conditions: Operator practiced with grader until he was familiar with operation of machine and also the technique of tip construction. Stakes were set indicating beginning of cut, bottom of dip on a 45° angle and termination of berm. Operator was allowed as many passes as was necessary to construct to the proper standard as required by road foreman, who was judging this test.

   Still pictures were taken at side before operation and after, and movies taken during operation for the purpose of analyzing maneuverability of the blade. Information recorded was - location, material, difficulties, operational sequence, time, soil moisture and foreman's rating of completed job.

B. <u>Maintenance of Dips</u>. Existing dips were selected which were in need of reshaping and sluff removal. Motion pictures of operation were taken for analyzing blade response to controls and the ability of the blade to follow an existing profile. At the same time observations were made to determine if the lift mechanism range was adequate for below grade extension while possessing sufficient lift above grade to complete the operation.

   Still pictures before and after were taken. Location, grade, road width, material, difficulties and reasons, operational sequence, time, soil moisture, blade response and control were recorded.



INTERCEPTING DIP

FIG. 6

IV. DITCHING

The purpose of this test was to determine the ability of the machine to function under difficult conditions involving extremely heavy work. The operation involved the use of the blade and scarifier in cutting dirt and rock and in removing large boulders by undercutting and pushing, and the blade and blade control mechanism in finish grading at the end of the operation. It also tested the ability of the machine to provide traction while working on a slope and pushing material uphill. The general toughness of the whole operation was a test of the stamina of the machine.

An area, 200 feet long and 32 feet wide, which was high in rock and boulder content, was selected. Test consisted of digging a 200-foot ditch on a 6% slope similar to shoulder construction on one side of a highway. The vertical depth of the ditch was 3 feet with cut bank on a 3/4-to-1 slope. The distance from the ditch line to the shoulder was 16 feet and constructed on approximately a 4:1 slope. All material was side cast beyond the 16 foot width, or beyond the 200 foot end limits. Operators were allowed to use blade and scarifier.

Information obtained was - location, grade, side slope, material, depth, width, distance, time, and appearance of the finished job. Still pictures before and after were taken, also movies of interesting or unusual incidents.

V. SCARIFYING

The purpose of the test was to determine the ability of the grader to loosen imbedded rock and to do normal scarifying work. Essentially, the test was for the purpose of bringing out the structural ability of the unit to do this kind of work under severe conditions.

This operation is very important. It is required in maintaining road material or a travelable surface on all roads, and is particularly needed after heavy storms.

After completion of the rough shaping of the ditch (Test No. IV), the inside slope area containing numerous imbedded rocks, was used for this test. Information recorded was - location, grade, width of scarifier swath, material, soil moisture, number of teeth used, depth scarified, time, operational sequence, operator reaction, failures, and time required to install teeth for operation. Time element was not important except to require operation at a reasonable speed. Still shots, before and after, and movies were taken.

VI. BANK SLOPING

The purpose of this test was to determine the ability of the graders to side-slope banks at any required slope from 1½-to-1 to 1/4-to-1.

This operation involved the use and adjustment of the control arms, the use of the circle, and general manipulation of the circle and arms assembly.

Sections of roads 500 geet long were selected in which banks at least 10 feet high existed, and included in-curves, out-curves and tangents.

Information recorded was - location, grade, material, distance, time, maximum height of cut, analysis of finished job, difficulties, and operator reaction. Still shots were taked of grader in position, and of road before, during, and after. Short movie sequences were taken to record the operation.

Bank sloping on Forest Service work is done largely on reconstruction or heavy maintenance work. Although it does not involve a very high percentage of total volume, the occasions of use require a highly maneuverable blade assembly.

VII. DRIFTING

The purpose of this test was to determine the ability of the grader to end-haul material. The operation involves the size, design and pitch of the blade controls.

Drifting is required continually in normal maintenance operations to remove slides, fill washouts, and restore surfacing.

Material for drifting operation was taken from a low cut bank extending 100 feet, moved across a 25-foot area, and placed in an area 75 feet long and 12 feet wide, to a depth of .6 of a foot, forming a finished road bed. At the end of each pass, grader with blade lifted returned to the far end of cut bank section.

Data collected included - location, distance, grade, material, angle of blade, pitch of blade, estimated yardage, material lost or picked up enroute, time, and operator reaction.

Time element was very important in this test since it reflected balance of power and blade size, ease and dexterity of blade movement and time consumed in shifting gears.

Still pictures were taken to show before and after operation, also movies to show dirt movement on blade, and amount of material being moved.

VIII. HORIZONTAL MOVEMENT OF WINDROW

The purpose of this test was to determine the ability of the machine to move a windrow of dirt laterally. It involved the size, shape and pitch of the blade, the tractive ability of the machine, and the functioning of the blade control mechanism.

This operation is used in all road mix oiling work and in construction of roads on flat terrain.

A section of road 1300 feet long, with an average grade of 9%, was designated as the test area. A large windrow was formed on one side of the road, and measurements made from established reference points. The grader in four passes was required to move as much material as possible to the opposite side of the road, forming a more or less uniform windrow. Lateral movement of dirt was determined by measurements taken at the reference points, and total yardage figured from cross section measurements taken every 100 feet. The elapsed time for the operation was recorded.

IX. SHAPING BERMS

The purpose of the test was to determine ability of the grader to form a berm 18" high with side slopes $1\frac{1}{2}$:1. This operation is of great importance on all roads using berms as a drainage control feature. This includes most of the road mileage in the California Region.

A section of road between 300 and 500 feet in length was selected and material in existing berm was spread over the road bed. Three passes were then made, ending up with the material forming a uniform berm on the outer edge of road.

Information recorded was - location, grade, material, distance and time. Still shots before, during, and after operation were taken.

X. HILL CLIMB

The purpose of the test was to determine the ability of the machine to climb grades up to 50% in both forward and reverse gears.

The site selected for the test had a runway with an overall length of 300 feet, which started level and gradually sloped up to a maximum of 49%. Graders were required to climb uphill forward and uphill backward, recording percent of grade at the forward point of stalling, if any. The decomposed granite surface of the hill was prepared before each run so no loose material hindered the test.

XI. UPHILL GRADING

The purpose was to determine the ability of the machine to climb uphill and do normal grading at the same time.

Road sections, 500 feet long, in which grades from 10 to 21% existed, were selected. One pass uphill was made.

Information noted was - location, material, soil moisture, grade, time, tendency of machine to drift under load, and appraisal by road foreman as to effectiveness of the work. Still shots before and after, and movies during operation were taken.

XII. ROAD GRADING

The purpose of the test was two-fold; first, to acquaint operator with the three-pass operation in road maintenance and, second, to provide an opportunity for observers to analyze the performance of each grader on a short section of road.

Sections of road 500 feet long were selected which were in need of maintenance, and which included in-curves, out-curves, turnouts and dips.

Operation consisted of three passes: cleaning the ditch of sluff, spreading and removing rocks and smoothing.

Information recorded was - location, grade, road condition as to ruts, amount of sluff, material, soil moisture, distance, time, maneuverability, difficulties, appearance of finished job, and operator's reaction. Still shots before, during, and after operation were taken.

XIII. ROAD MAINTENANCE - LONG SECTION

The purpose of this test was to determine the overall ability of the grader to do all of the important functions of a road maintenance job. These operations include slide and sluff removal, dip maintenance, normal and fine grading, berm construction, and drifting. Bank sloping was not included. Operation was up and down hill and around minimum radius curves (under 35 feet), and involved the use of all grader controls.

This work is the primary purpose for which motor patrols are purchased and constitutes the larger portion of their use.

Sections of truck trail with grades up to 20% and needing maintenance work, two miles in length, were marked by means of flags. Picture stations were marked for the purpose of before and after photographic records which would depict the different functions common to the operations of rock removal, sluff removal, dip cleaning and shaping, and fine grading. Three passes were required.

Information recorded was - location, material, distance, time, amount of work to do in rock, sluff removal, number of dips to shape, and number of minimum curves.

Appearance of the finished job was appraised by engineers and road foremen.

Fine Grading

On the two mile maintenance section an area suitable for fine grading was selected where no appreciable amount of rock was present.

Results of the operation were carefully analyzed for absolute control of the blade, since this test was considered as a measure of the ability of the grader to handle surfacing operations.

Still pictures before and after were taken to indicate the degree of improvement resulting from the operation.

TEST RESULTS & COMPARATIVE DATA

To facilitate comparison and to conveniently tabulate the various date obtained from the test, Table I, Comparative Data, has been prepared.

The date recorded in column one (1) are taken from the manufacturers' published specification sheet and cover the standard production model only.

In column two (2), are summarized the data taken from the "flat land" and "field test" sections of the report. Discrepancies in this column from the manufacturers' ratings as shown in column one (1) may be attributed to definition or deviation from standard on the test machine. Where considered necessary, deviations are discussed under the Discussion of Test Results.

In columns three (3) and four (4) are the data of other graders tested in this class. The intent here is to show the maximum and minimum of the other data collected. It should be noted that the maximum as shown does not necessarily infer the best, particularly where time is involved. Constant appraisal of the item under consideration will be necessary to properly evaluate the tabulated results.

TABLE I

COMPARATIVE DATA

Flatland Tests

Items	Mfg. Spec. Std. Machine (1)	Rome Test Mach. (2)	Other Graders Tested Maximum (3)	Other Graders Tested Minimum (4)
WEIGHT	23,850	25,100	27,950	22,560
Weight on front whls.	7,500	7,400	9,350	7,350
Weight on rear wheels	16,350	17,600	19,300	13,150
Blade pressure	12,000	12,300	18,520	12,720
Scarifier pressure	8,425	8,900	10,460	8,200
DIMENSIONS				
Length overall	27'-0"	27'-0"	25'-8"	24'-3"
Width overall	96"	96"	94-3/4"	91-3/4"
Height overall with cab	123"	123"	128"	116¼"
Height overall less cab	82"	82"	104"	89"
Height inside cab	-	72"	75½"	69"
Wheel base	19'-6"	19'-7"	18'-11"	18'-8"
Tread, Front (Center to center of tire)	83"	82-3/4"	83¼"	79"
Tread, Rear (Center to center of tire)	82"	82"	80"	78¼"
SPEEDS				
Min. forward mph	2.32	-	2.37	1.7
Max. " "	20.18	-	25.2	15.0
Min. reverse "	3.38	-	3.7	1.74
Max. reverse "	4.63	-	6.13	4.1
Number Forward	8	8	8	6
Number Reverse	2	2	3	2
ENGINE				
Brake HP	113	113	104	76
No. of cylinders	6	6	6	4
RPM - Governed max.	1800	1930	1990	1555
CAPACITIES				
Fuel tank (Gals.)	45	45	60	54
Cooling system (Gals.)	10½	10½	20	6½
Crankcase (Qts.)	20	20	23	16
TIRES				
Size, Front	8.25 x 24	13.00 x 24	14.00 x 24	13.00 x 24
Size, Rear	13.00 x 24	13.00 x 24	14.00 x 24	13.00 x 24
Ply	-	12	10	8

TABLE I (Continued)

COMPARATIVE DATA

Flatland Tests

Items	Mfg. Spec. Std. Machine (1)	Rome Test Mach. (2)	Other Graders Tested Maximum (3)	Other Graders Tested Minimum (4)
BLADE ASSEMBLY				
Moldboard - Length, width, thickness	12'x24"x3/4"	12'x24"x3/4"	13'x22½"x3/4"	12'x22"x5/8"
Blade side shift (R&L) (Mfgrs. Rating)	36"	26½"	69"	29"
Right blade side shift from center position (circle shift)	-	16½"	25¼"	19"
(circle shift & link adj.)	-	22"	38¼"	19"
(circle, links & moldboard adj.)	-	54"	62½"	51"
Blade lift above ground - Sect. 1 - Test E	-	15¼"	16"	14-3/4"
Blade depth below ground - Sect. 1 - Test E	-	5"	23½"	8¼"
Pitch positions - number for tilting	15	15	13	6
Max. shoulder reach	81"	77¼"	88½"	75"
Bank slope angle (Test conditions 1-C-3)	-	52°	74°	57½°
Circle diameter	54"	54"	63"	54¼"
Degree turn blade w/scar. teeth	-	296°	320°	302°
Degree turn w/o scarifier teeth	360°	360°	360°	320°
Lifting speed (Approx.)	2.86"/sec.	1.53"/sec.	2.37"/sec.	.98"/sec.
SCARIFIER - V TYPE				
Weight	1,132#	-	1,475#	1,300#
Swath width	46"	46"	46"	46"
Teeth number	11	11	11	9
Teeth size	1"x3"	1"x3"	1¼"x3½"	1"x3"
Pitch positions	1	1	5	1
Pressure max.	8,425#	8,900#	10,460#	8,200#
WHEEL LEAN				
Max. L	-	15½°	21½°	19½°
Max. R	-	11°	22½°	20°
GROUND CLEARANCE				
Behind blade (Wheels Vert.)	-	10-3/8"	13½"	11-3/8"
Front blade (Wheels Vert.)	20	19-3/8"	27½"	14"
Behind blade (Wheels Max. Lean)	-	10-3/8"	13½"	11-3/8"
Front blade (Wheels Max. Lean)	-	19"	27"	20-3/4"

TABLE I (Continued)

COMPARATIVE DATA

Flatland Tests

Items	Mfg. Spec. Std. Machine (1)	Rome Test Machine (2)	Other Graders Tested Maximum (3)	Other Graders Tested Minimum (4)
TURNING				
Turning radius (Inside wheel) R	-	27'-5"	27'-9"	21'-10"
Turning radius (Inside wheel) L	-	26'-9"	29'-3"	22'-9"
Turn. radius - Ave. inside wheel ÷ ave. road width	40'-0"	40'-5½"	41'-2½"	30'-6"
Road width to turn R	-	13'-5"	13'-10"	8'-0"
Road width to turn L	-	13'-4"	13'-2½"	8'-2"
Field Tests				
ROAD WIDTH FOR TURNING - NUMBER OF BACKUPS				
35 Foot Road	-	4	3	2
30 Foot Road	-	8	7	3
DIP CONSTRUCTION (Time)	-	16 M. 43 S.	27 M. 0 S.	14 M. 36 S.
DITCH CONSTRUCTION (Time)	-	11 H. 33 M.	10 H. 22 M.	8 H. 20 M.
DRIFTING (Cu.Yds./Min.)	-	.92	1.29	.97
MOVE WINDROW (Cu.Yds. Feet/Min.)	-	96.5	149.0	85.5
SLIDE (Climb over in min.)	-	22 M. 59 S.	50 M.	15 M. 57 S.
INSIDE CURVE				
Road width needed - Ave. L & R	-	19'-11"	19'-11½"	9'-7½"
ROAD MAINTENANCE (Miles/Hr.)	-	.51	.635	.48
BRAKE TEST - @ 18 mph Cal. Veh. Code Min.	30	32	38	15

TABLE I (Continued)

COMPARATIVE DATA

Field Tests

Items	Mfg. Spec. Std. Machine (1)	Rome Test Machine (2)	Other Graders Tested Maximum (3)	Other Graders Tested Minimum (4)
WALKING TEST (1)				
Paved highway (4.2 Miles)	-	20.9 MPH	24.6 MPH	15.8 MPH
Dirt highway (1.9 Miles)	-	15.5	17.25	12.35
Total highway (6.1 Miles)	-	18.9	19.94	14.50
WALKING TEST (2)				
Uphill T.T. (1.35 Miles)	-	6.37 MPH	6.66 MPH	4.49 MPH
Downhill T.T. (2.3 Miles)	-	10.63	16.24	9.13
Total T.T. (3.65 Miles)	-	8.52	9.98	7.70

DISCUSSION OF RESULTS

Flat Land Tests

WEIGHTS

The weight distribution as shown from Table 1 was found to conform very closely to that of the other tandem graders. Table IIA below shows the maximum deviation from the average of the other tandems to be less than 5%.

TABLE IIA

	Weights	Distribution - Percent	
		Rome	Other Tandems
Total	25,100	100	100
Front	7,400	29.5	30.3
Rear	17,600	70.5	69.7
Scarifier	8,900	35.5	34.3
Blade	12,300	49.0	53.8

Accordingly, the weight distribution for the Rome grader is considered in conformance with standard practice.

The blade pressure of 12,300 lbs., as recorded for the Rome, was the lowest of all graders tested. As shown in Table I, other graders ranged from 12,720 to 18,520 lbs. While the differences in themselves have little significance, since proper balance between blade pressure and tractive effort must be maintained, it may be well to note that even though total weight of the Rome is next to the heaviest of all graders tested, blade pressure is the least.

It should also be noted that in the process of determining blade pressure, difficulty was experienced in getting the hydraulic system to raise the front end of the grader on the blade. It was here that the first indication of possible trouble with the hydraulic system was evidenced. This is discussed later in the report.

Scarifier pressure was found to be well within the average, and its determination was made without difficulty.

The question of weight distribution was raised several times during the field test because of what appeared as an excessive tendency toward loss of traction and drifting. It is evident from Table IIA that the difficulty was not due to weight distribution.

An analysis of the overall weight per horsepower, and drivewheel weight per horsepower was made. The figures provide material for interesting discussion and are shown in Table IIB.

TABLE II-B

	Rome	Maximum	Minimum
Overall weight	25,100	27,950	24,500
Drivewheel weight	17,600	19,300	17,150
Horsepower	113	100	104
Pounds per hp (total wt.)	222	280	236
Pounds " " (drivewheel wt.)	156	193	165

The two graders which were classed as drifters had total weight horsepower ratios of 236 and 222. Drivewheel to horsepower ratio was 165 and 156 respectively. Graders with a ratio of 247 and up for the overall weight were noted as stable in performance. A comparable figure for dirvewheel ratio was 172.

It is not the intent of this report to determine the ideal ratio, but merely to suggest that this weight to power relationship may play an important part in performance of a grader. Possibly if the analysis were carried further to develop weight per pound of rim pull, additional evidence could be presented to show departure of the Rome 402 from the design practice of other manufacturers.

From the data above, and field reaction of observers and operators, there is reason to believe that the claims of excessive drifting of the Rome grader are well founded.

DIMENSIONS

Although not the heaviest machine, the Rome 402 had a wheelbase in excess of the others by 8", was $1\frac{1}{4}$" wider, and 16" longer than any of the other machines tested. The additional wheelbase and the excess length, which was mainly overhang behind the tandems, did not greatly effect the minimum turning radius of the machine, although it was a definite detriment when attempting to turn the machine around in confined spaces. The height clearance inside the cab of 72" was second from the lowest and is considered slightly low when it is remembered that the unit shown as minimum in the Comparative Data, Table 1, had a 6" trough set into the floor plates that would increase height to 75". In height overall with cab, and height less cab, the Rome 402 is well within the average of all units tested.

The sizes and weights of the box section frame are average as compared to other machines. However, due either to design or weight distribution on the frame itself, the frame showed extreme flexibility. From chalk marks put on the rear of the cab, it was shown that the relative motion between the vertical center lines of cab and engine was approximately 2°. This flexibility was extremely noticeable in the heavier work such as encountered in the ditching tests, but was evident during all operations. Flexing in this respect will ordinarily result in eventual structural failure and may be a decided factor in blade flexibility complaints which are discussed under Blade Operation. The arrows in photograph, Fig. 7, show the range of this movement.

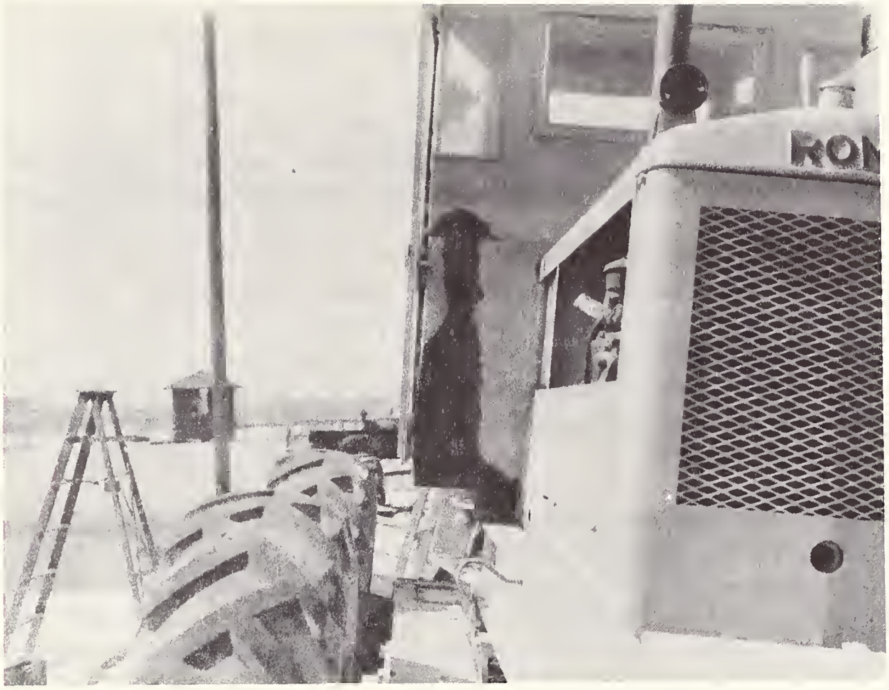


Fig. 7. Flexing shown by Arrows on Cab

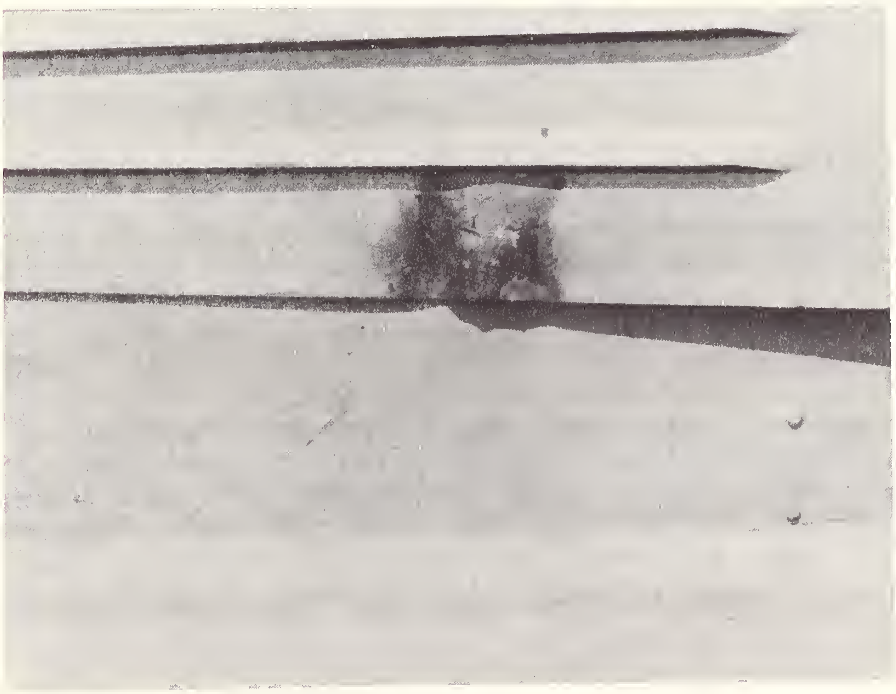


Fig. 8. Hood Correction

ENGINE

The engine was a Model DWXLD Hercules, six cylinder, four stroke cycle diesel with a bore of $4\frac{1}{2}$" and stroke of 5", displacement of 426 cu. in. and rated at 113 Brake Horsepower maximum at a governed speed of 1800 RPM. The engine has a crankcase capacity of 20 quarts and the recommended fuel is Diesel No. 1. Electric starting is provided with an ether pill assist for conditions when temperatures are adverse.

The engine furnished with the unit was not standard up until time of test. It was reported that this engine was equipped with a high torque cam in order to overcome apparently unsatisfactory torque characteristics in previous models. It was not possible to check for the high torque cam or verify the need for change because of no basis for comparison.

It was the consensus of operators and others in attendance at the test that engine performance was equal to or surpassed any of those on the field. Except for engine surges at idle or partial load, which is conceded a characteristic of this type diesel, no complaints were noted regarding performance. Even though No. 1 Diesel was recommended by the factory for use in this engine, no difficulty was experienced with the government contract Diesel fuel used during the test.

Two items, however, associated with the engine and attributed mainly to poor workmanship and inspection were recorded.

The generator drive and driven pulleys were not in alignment. While not serious, continued operation in this condition would result in premature belt wear.

The air compressor belt and pulley rubbed heavily on the left hood side. A block of wood had to be wedged under hood to obtain running clearance. until corrected by the factory representative. Correction was made by heating and bending the hood to provide necessary clearance. Refer to photograph - Fig. 8.

SPEEDS

The transmission had eight speeds forward and two reverse. Gear reduction was such as to provide adequate variation for all types of work. The comment here applies only to speed and is not intended to cover the transmission as a mechanism for changing speeds, or control of the grader at the various operating speeds. This is discussed elsewhere in the report.

I. BLADE OPERATION

A. Operation of Circle. On preliminary inspection, the circle showed a full width crack on the inside vertical section. This crack was welded at the Forest Service Shops, under Direction of the Rome Company's representative before tests were begun.

The time required for one cycle of operation of the blade circle was 2 minutes and 19 seconds. This is approximately one-sixth longer than the other hydraulic machine tested, and is much slower than the time required for mechanically operated machines which ranged between 40 and 52 seconds. On the unit tested, a complete 360° cycle was obtained with difficulty. Scarifier lift links had to be shortened and, even then, top of moldboard dragged on scarifier block. The lengthwise tilt of the circle and drawbar has a direct bearing on the ease with which the blade can be maneuvered. The circle on all other graders tested was practically at horizontal plane in relation to the ground level. The Rome was $4\frac{1}{2}$ inches higher at front than at rear. To turn the blade and maintain ground clearance, the circle had to be tilted, by use of the lift arms. This had the effect of requiring the operator to use three controls simultaneously (right and left lift and circle reverse) when not traveling, and a fourth steering control if this operation was attempted while in motion. All other machines, when equipped with 12-foot blades, had no difficulty in operating through a 360° cycle with adequate clearance when scarifier teeth were removed. One machine equipped with a 13-foot blade had a blade cycle of only 320° due to fact that the blade at one end failed to clear the scarifier block by $1\frac{1}{2}$". This particular machine would clear both scarifier block and teeth when equipped with a 12-foot blade. Reel 1 of the final motion pictures of the test show the definite dragging of the blade of the Rome on concrete slab and scarifier when attempting to make a complete circle of the blade.

B. Locking Devices. Blade circle did not have a positive locking device to prevent shifting of the blade under load. Difficulty was experienced due to shifting of the loaded blade in the first attempt to run the windrow test. At the time it was thought that the selector valve was defective and a new one was ordered from the factory. However, in the meantime, sticking of the circle mechanism control valve stem was repaired and, with by-passing in hydraulic system eliminated, the circle stayed in position with slight creep under heavy load. Only one machine tested had a separate positive cab controlled circle lock. The lock on this machine had the disadvantage of not being able to be released under blade load. Mechanical control graders depended on worm and worm gears with friction drags on worm drive to lock controls in position.

C. <u>Bank Sloping Positions</u>. The Rome Model 402, like all other machines tested, had no special attachments for bank sloping. However, it was necessary to shift the <u>ball</u> connection from the lower to the upper octopus arm, as well as to shift linkage when changing for bank sloping. All other machines tested were able to reach bank slope position by shortening and lengthening linkage only. More difficulty was experienced in obtaining bank sloping position with this unit than with any other machine. In maneuvering to reach bank sloping angles considerable interference of scarifier lift links and circle drawbar was evident. Scarifier lift links were bent out of line approximately two inches, as shown in photograph - Fig. 9.

Fig. 9. Scarifier Arms Bent by Drawbar

The following tabulation, Table III, shows the height of the blade tip and the position of the heel of the blade for various bank slope positions, together with maximum and minimum of the same measurements for other machines tested.

TABLE III

Bank Slope Blade Positions

Bank Slope	Angle	Measurements (In inches)	Rome	Other Machines Tested Maximum	Other Machines Tested Minimum
$1\frac{1}{2}$:1	34°	Height of tip above ground	65	51	32
		" " heel " "	0	0	0
		Distance heel inside ref. line	24	0	0
		" " outside " "	0	0	0
1:1	45°	Height of tip above ground	80	81	49
		" " heel " "	0	0	0
		Distance heel inside ref. line	$10\frac{1}{2}$	0	0
		" " outside " "	0	0	0
3/4:1	53°	Height of tip above ground	94	112	$82\frac{1}{2}$
		" " heel " "	0	0	0
		Distance heel inside ref. line	$6\frac{1}{2}$	0	0
		" " outside " "	0	6	0
$\frac{1}{2}$:1	63°	Height of tip above ground	84	123	106
		" " heel " "	0	0	0
		Distance heel inside ref. line	0	0	0
		" " outside " "	$5\frac{1}{2}$	$15\frac{1}{2}$	0
$\frac{1}{4}$:1	76°	Height of tip above ground	109	$138\frac{1}{2}$	$76\frac{1}{2}$
		" " heel " "	$6\frac{1}{2}$	0	0
		Distance heel inside ref. line	0	0	0
		" " outside " "	12	23-3/4	12-3/4

It should be noted that on slopes up to 53° the heel of the blade was inside the wheel reference line, as shown in photograph - Fig. 10. It had the effect of making the blade incapable of touching a bank below the point where the blade passed the tires. Later field trials showed this to be true unless the machine was driven up on the bank being sloped. The photograph shown in Fig. 11 clearly indicates that in order to slope the bank, it was necessary for the machine to be driven along the bank itself. If the machine was not run on the bank, gouging of the road with the heel of the blade resulted. The particular photo shown was on an out-curve. On in-curves and tangents this difficulty would be aggravated.

Fig. 10. Bank Slope Angle $1\frac{1}{2}$:1

Fig. 11. Tandem Tracks on Slope

As shown in Table III, none of the other machines tested had difficulty reaching the required bank slope angle with the heel of the blade on or outside the reference line.

The following items relative to construction details that contributed to the failure of the machine in attempts to bank slope are noted below:

1. Wheel tread of the tandem was 2" wider than for any other machine.

2. Throw of lateral link was less than that of any other machine tested.

3. Total travel of blade with octopus arms and by telescoping lift links from minimum to maximum was less than that of any of the other machines tested.

4. Scarifier drawbar and lift links interfered with full swinging of the circle drawbar.

With the blade extended in bank slope angles, considerable drop was noted when lowering blade. This resulted in over-control in blade maneuvering. Looseness of linkage, linkage arm caps and ball studs, sponginess of hydraulic system, lack of restrictor plugs in discharge side of hydraulic cylinders, and extreme flexibility of the grader frame were all contributing causes to this tendency toward over-control. Sponginess of the hydraulic system was attributed to air in the system. In spite of bleeding of the system this condition continued.

D. <u>Side Shift</u>. With the blade set in center normal operating position, it could be shifted $16\frac{1}{2}$" to the right with the lift arms. This was with the drag link set for right hand operating position. With the drag link set for left hand operating position, the shift of the blade could be reversed to an equal left shift distance. This compared with a minimum of 19" and a maximum of $25\frac{1}{4}$" for the other machines tested. The time for the shift from center position to maximum right and return was 54 seconds, as compared with the minimum of 42 seconds and maximum of 66 seconds for the other machines. Due to the different distances of shift, these figures of time were reduced to inches of shift per second, and are shown in the following table.

TABLE IV

Blade Side Shift

With Blade Centered on Circ.	Rome	Other Machines Tested Maximum	Other Machines Tested Minimum
Distance Right	$16\frac{1}{2}$"	$25\frac{1}{4}$"	19"
Shift in. per Sec.	.61	.98	.76

The amount of linkage, and points of possible wear with resulting blade instability, were far more numerous than those on any of the other machines tested. Considerable maintenance and tightening of loose brackets, bolts, ball studs, and other parts of the linkage assembly was necessary. The ball studs had straight shanks and once they had loosened in the linkage arms deformed the holes in which they were installed. This made it difficult to tighten them and would be a constant source of maintenance. The ball stud in the lateral shift arm at the control cylinder was repeatedly tightened. In spite of this, before conclusion of the test it was noted that sufficient wear had occurred so as to make early replacement of the shift arm necessary.

The time required to offset the blade on the circle was not obtained with accuracy. Binding of the blade on the support brackets, and jamming of blade slide rails due to dirt and rock varied the time from 30 minutes to 1 hour. On the machines tested there were thred methods of blade shift: power ram, unbolting and rebolting blade on blade beams, and blade slide. Time for blade shifting on machines where blade was unbolted, shifted and rebolted, averaged 9 minutes 9 seconds. Machines using slide mechanism averaged above 20 minutes.

Blade shifting was first attempted by forcing blade into ground, as is standard for this type. Second attempt was against a concrete abutment, and third attempt against a telephone pole. Binds in eigher the locking device or moldboard arms made shifting extremely difficult. The blade was finally slid to position by using a hammer to jar the bracket support arms after which the circle was swung to near vertical and the blade slid into position. This operation consumed 45 minutes.

The locking device on the moldboard proved difficult to operate and was an added hindrance to the shifting operation. Hand latch is exposed and seemingle is vulnerable to damage.

E. Blade Lift. The maximum blade lift above ground, maximum level below ground, angle of lift right and left with blade centered, and the clearance between blade cutting edge and bottom of circle are given in the comparison Table V.

TABLE V

Blade Lift

With Blade in Normal Operating Position	Rome	Other Machines Tested Maximum	Other Machines Tested Minimum
Max. lift above ground	$15\frac{1}{4}$"	16"	14-3/4"
Time for max. lift	10 sec.	15 sec.	6-3/4 sec.
Rate of lift (in. per sec.)	1.53	2.37	.98
Max. drop below ground	5"	$23\frac{1}{2}$"	$8\frac{1}{4}$"
Clearance blade to circle	$24\frac{1}{2}$"	$28\frac{1}{4}$"	25"
Max. angle right	$13\frac{1}{2}^{\circ}$	$15\frac{1}{2}^{\circ}$	8°
Max. angle left	$13\frac{1}{2}^{\circ}$	$12\frac{1}{2}^{\circ}$	8°

In the above group of operations the Rome was average, compared to the other machines with the exception of blade drop below ground. This deficiency was particularly evident in operations such as drainage dip construction where maneuvering of the blade below normal ground level is necessary.

The telescoping circle lift links and the side shift links had pins 1/2" in diameter, as against 9/16" for other machines. Pins were not tapered at the ends and placing them in holes was difficult. The cotter keys used were 3/32" and nearly all were lost during operation due to breakage in attempts to remove them from the pins. Lift link pins were battered at the ends in attempts to drive them through connecting holes. They had to be tapered on an emery wheel to ease installation.

F. Blade Reverse. In attempting to reverse the blade for back-up operation, the same difficulties were encountered that have been noted under Blade Circle. Any time it was necessary to pass the blade under the scarifier, interference between scarifier, blade and concrete slab was noted. A complete redesign of eigher scarifier, drawbar or moldboard will be necessary to eliminate this trouble.

G. Pitch Positions. The comparative table of pitch positions and angle of pitch is given in Table VI.

TABLE VI

Blade Pitch

	Rome	Other Machines Tested Maximum	Minimum
PITCH Forward	$+39\frac{1}{2}°$	$+43\frac{1}{2}°$	$27\frac{1}{2}°$
PITCH Rear	$+1°$	$-17°$	$+9°$
PITCH Positions	15	13	6

The angle of pitch and number of pitch positions of the moldboard on the Rome 402 compared favorably with that of the other units tested. The 15 pitch positions allowed for closer adjustment of the moldboard than for any of the other machines. Pitch position arms were apparently weak, and one of them was badly bent during the tests.

H. Visibility. Visibility of wheels and blade is of especial importance in Forest Service operations where steep grades, narrow roads, and short radius curves are prevalent. None of the units tested had complete visibility, since all had mechanisms that partially obstructed the operator's view of either blade or wheels. It was the consensus of observers that the Rome 402 rated number four of the five machines tested. Octopus arm and hydraulic valve assemblies located in front of the windshield were the chief causes of lack of visibility.

II. WHEEL LEAN

Test date, for the unit as received from the factory, is shown in the table with maximum and minimum of other graders tested.

TABLE VII

Wheel Lean

	Left	Right
Rome	$15\frac{1}{2}°$	$11°$
Maximum Other Tandems	$21\frac{1}{2}°$	$22\frac{1}{2}°$
Minimum Other Tandems	$19\frac{1}{2}°$	$20°$

The $4\frac{1}{2}°$ deviation from maximum left to maximum right was considered excessive and an indication of poor workmanship in assembly. The variation in other graders checked did not exceed $1\frac{1}{2}°$. These positions are fixed at time of assembly, with no means of adjustment. Correction would be difficult.

Fig. 12. Rome Wheel Lean - Right

Fig. 13. Cross Stabilizer Wear

There was no published data to indicate what the designed wheel lean should be. It is assumed, however, that when corrected to equalize right and left lean, the final setting would approximate 13°. This is considerably less than the lean accepted by other manufacturers as desirable.

Had the Rome been capable of a 20° right and left wheel lean, it is possible that the movement of the front end due to side thrust as noted in field tests, and shown in the movies would have been reduced.

The leaning wheel cross stabilizer rod was incorrectly assembled, allowing it to rub heavily on the main frame at point of crossing. When checked after completion of test, wear on the stabilizer had progressed to 3/16 inch. Refer to Fig. 13.

During the final field test, difficulty developed with the leaning wheel control. This is discussed later in the report under "Field Tests".

III. GROUND CLEARANCE.

Ground clearances for the Rome are listed in Table VIII with maximum and minimum valves for the other tandem graders tested.

TABLE VIII

Ground Clearance

	Rome	Maximum Other Tandems	Minimum Other Tandems
Wheels Vert.-Behind Blade	10-3/8"	13½"	11-3/8"
Front of "	19-3/8"	27½"	22"

Ground clearances for the Rome grader were less than the other tandem units tested. In only one instance was less clearance recorded, and that for the front axle of a grader which was not a tandem.

Tire sizes were favorable in the case of the Rome, as the unit was equipped with 13.00x24 - 12 ply tires, which were second to the largest tires on the field.

Even though clearances were low, it was not apparent that operational difficulties could be directly attributed to this condition. Undoubtedly, it was a factor in slide removal, windrow test and, on occasion, during the ditching operation, but a direct association with overall results was not noted.

IV. FRONT AXLE TREAD

Test data are shown in Table IX.

TABLE IX

Front Axle Tread

Rome	Maximum Other	Minimum Other
82-3/4"	83-1/4"	79"

Three of the five graders tested had front axle treads of less than 80".

It will be recalled that narrow width front axles were preferred in graders of the past. In certain instances it was considered justifiable to cut front axles and shorten them so as to increase maneuverability on short radius turns. With the advent of large tires on front wheels, it appears as important to confine front axle tread if the reasoning of the past still stands.

With the possible exception of bank sloping, there were no operational difficulties noted which might be attributed directly to excessive tread.

V. SERVICING REQUIREMENTS

Records are kept of the fuel used by all of the machines tested. The table below shows fuel consumption and hours operated for the test period.

TABLE X

FUEL CONSUMPTION

	Rome	Max. Other	Min. Other
Fuel - gal.	220	272	209
Hours	85	113	58
Gal./Hr.	2.59	3.76	2.41

On the basis of the record, it would appear that the Hercules engine has a very favorable fuel consumption considering its horsepower. These data, however, cannot be taken as true indications of consumption because of the uncertainty as to comparable operating conditions.

The total number of service points and the number requiring daily, weekly and monthly checks are shown in Table XI.

TABLE XI

SERVICE DATA

	Rome	Grader A	Grader B	Grader C	Grader D
Total Serv. Pts.	101	112	103	114	70
No. Daily Serv.	92	4	46	63	40
No. Weekly "	6	77(20 hrs.)	34	50	9
Other	3	31	23	1	21
Total Points to Serv. during Wk.	466	174	264	365	209

The data in the above table is not exactly in accord with the manufacturers' recommendations. This is primarily because of the difficulty in determining the actual lube points from the instructions furnished, and also because of the use of other than daily and weekly periods.

The table indicates that the Rome has considerable more points requiring daily service than any of the other graders tested. When computed on the basis of one week's operation, the differences became more noticeable.

While the conclusions that could be drawn from the table may be considered insignificant, the problem of lubricating machines in important. Each point requiring lubrication is a potential source of trouble if not serviced. Time for servicing, particularly daily service, is most often lost time from production.

It does appear that manufacturers would be interested in keeping service labor to a minimum.

VI. TIRES AND RIMS

Tires as furnished were Firestone 13.00x24 - 12 ply, and rated with the heaviest in the 13.00 size. Final inspection on completion of test showed tires to be badly worn and cut. See Figures 14 and 15.

Fig. 14. Tire Cut - Rear Tandem

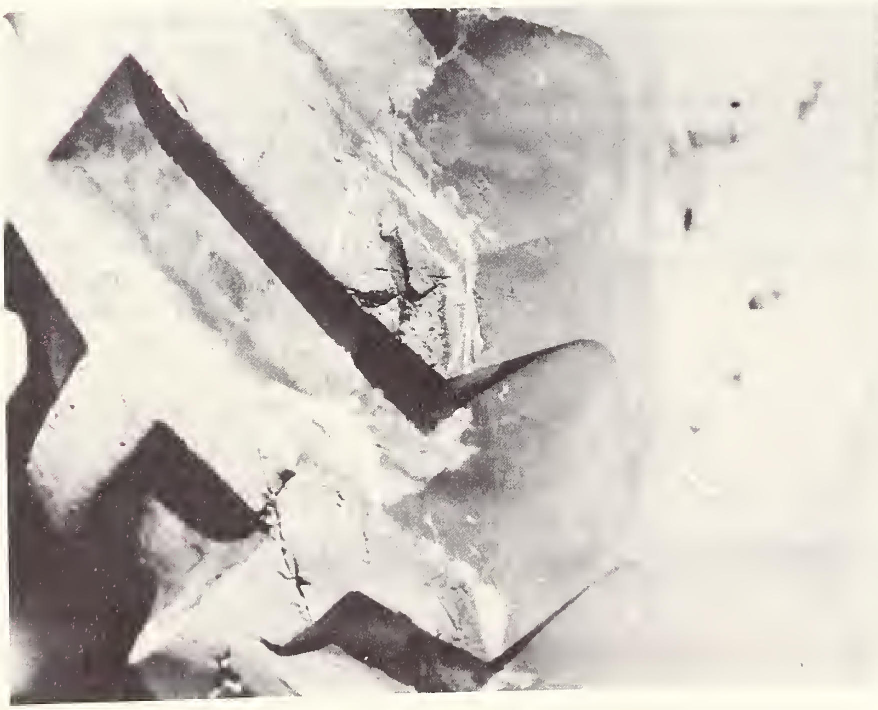


Fig. 15. Tire Bruise - Rear Tandem

Notes taken from the field data are listed below for comparison.

Rome - "Tires badly worn and cut."
Grader A - Wear - "Negligible", Breaks - "None"
" B - wear - "Negligible", Breaks - "No breaks"
" C - Wear - "Very little wear", Breaks - "None, some rock cuts - not serious."
" D - Wear - "Negligible", Breaks - "None (1 Small cut (sidewall) R.R. tandem)".

Analysis of the data and inspection clearly revealed that the Rome tires were subjected to more abuse than any of the others. In an effort to analyze the results, due consideration was given operators and test conditions. Nothing was apparent that indicated abnormal circumstances or abuse in the case of the Rome. To the contrary, the consensus of observers indicates that at least two other tandems had consistently more rough treatment.

It appears logical to conclude that the tire abuse could be directly attributed to the drive weight horsepower ratio of the grader, previously mentioned under "WEIGHT". Excessive slippage could have occurred which resulted in the tire abuse recorded. This becomes more logical when it is recognized that the only abuse recorded was on the tandem tires.

Classification data on the rims were not available, except that they were drop-center with lock ring.

The tire rims are secured to the wheels by lug bolts and nuts. To further prevent rim slippage a lug on the inner surface of the rim engages a notch provided in the wheel. On two occasions, all lug bolts were tightened after noting that rims were shifting about 1/4" at the lugs. During the ditching test, the rim on the right front tandem slipped, causing damage to notch in wheel. See Figure 16.

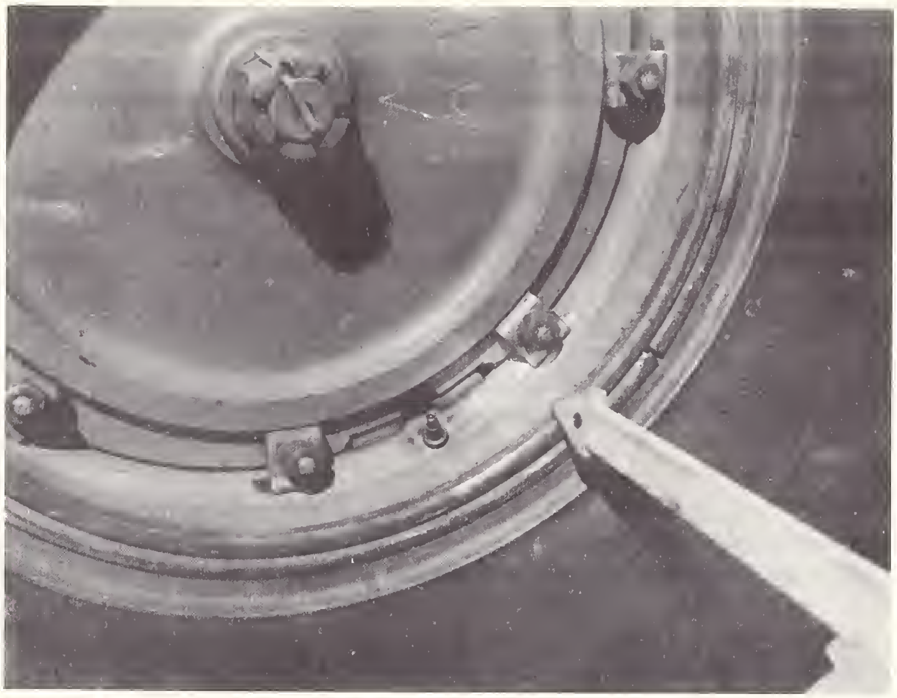


Fig. 16. Rim Slip

Previous experience with rim mountings of this type indicates that satisfactory operation can only be obtained by welding lugs solidly to rim. It is recognized that the rim is of standard make and designed for grader service. The fact remains, however, that the rim failure on the Rome was the only trouble of this kind experienced during the entire test.

VII. TANK CAPACITY

Comparative tank capacities are shown in Table XII.

TABLE XII

FUEL TANK CAPACITIES

Rome	Max. Other	Min. Other
45 gal.	60 gal.	54 gal.

No difficulty was evidenced during the test with tank capacity. Apparently the 45 gallon capacity was sufficient to run the grader between servicings.

It should be noted, however, that the fuel tank servicing the largest engine had the least capacity.

After checking, it was determined that another grader manufacturer with a smaller engine had previously used a 43 gallon tank, but either by choice or demand, had increased the capacity to 56 gallons.

By comparison at least, a larger fuel tank for supplying a 113 HP engine appears in order.

VIII. REMOVAL OF WINDOWS, DOORS, AND CAB

The cab on the Rome grader could be removed in approximately three hours in a shop. Doors, windshield, and rear cab glass could be removed in about 40 minutes by disconnecting two hinges for each.

The problem in connection with cab, door, and window removal was almost the same for all graders, with the possible exception of one. This unit had hinge-pins for removing windshield, rear cab glass and doors.

All cabs could best be handled with shop facilities and required considerable removal of bolts to effect demounting.

IX. LIGHTS

Intensity of lights, when measured with a Weston meter three feet from the light source, varied from slightly under 800 to 1200. The value as found for the Rome was just above 800. From the limited testing of lights on all graders, it was concluded that they were all adequate for travel illumination, but possibly would not comply with State Highway codes in all instances.

There appeared to be no standard for mounting the lights. Locations varied from top of cab to bottom of cab, and on one unit they were mounted on the lift rams. Some lights were adjustable, some were not. Some were protected, others were not. Some allowed for blade illumination, while with others it was not possible to see the blade. In no case were the differences because of lights or mountings considered serious.

Data recorded for the lights as furnished with the Rome are tabulated below:

Location	- Top of cab
Number	- Two
Weston intensity	- +800
Protected	- No
Adjustable	- Yes
Illuminated blade	- Yes - if adjusted
Adequate for highway travel	- Yes

The observers agreed that in future consideration of lights for motor patrols, more emphasis should be placed on adjustable mountings which will permit night illumination of the blade, protected lens on forward lights, and some provision for backup lighting.

X. ENGINE STARTING

The average time and temperature for four cold starts is shown in Table XIII.

TABLE XIII

	ENGINE STARTS		
	Rome	Max. Other	Min. Other
Average Time	10 Sec.	133 Sec.	49 Sec.
Average Temp.	50°	59°	42°

No difficulty was experienced with starting the Hercules Diesel engine at any time during the test. Starts were consistently faster than on any of the other machines with an average time far below the nearest engine. At no time was it necessary to use the ether pill assist even though starts were made at temperatures as low as 42°. Engine starting for the Rome is classed as superior to any of the other machines tested.

Field reaction to the use of ether pills was adverse at the beginning of the test, but was conceded to be a practical method toward the end. Actuallly, the prodedure is simple. In the opinion of the observers, the two engines equipped with ether assists were rated the highest in their ability to make fast starts.

XI. OPERATION OF CONTROLS

Considerable difficulty was experienced with the controls and associated mechanism of the Rome Grader. The discussion here is confined only to the actual controls as contained in the cab and the immediate linkage. Further discussion under "Final Inspection" will cover the r elated mechanism.

1. Hydraulic Hand Controls. When the grader was received, the hydraulic hand control levers interfered with each other. The two outer levers had to be bent to clear before using the machine. Two levers broke at the weld in bending. Inspection of the weld indicated a surface tack only.

The controls for leaning wheels and left blade lift were sticking early in the test, causing over-control of these two functions. The factory representative effected satisfactory temporary repair to these two controls by removing paint from valve surfaces and using emery cloth on the working surfaces. Difficulty with the control valves was recurrent and it was necessary to repeat the original corrective measure to effect satisfactory operation. As of the close of the test, these controls and the valve assembly were still giving trouble. Close inspection revealed pits in the valve cylinders, indicating corrosion, which apparently had caused the difficulty. For satisfactory continued operation the material used in the valve assembly should be corrosion resistant. It was not possible to check definitely, but it appears that it is not.

2. Shift Levers. The hi-low shift lever interfered with the main shift lever when it was in back (hi) position. Refer to Fig. 17.

Fig. 17. Shift Lever Interference.

Both gear shift levers were 32" long. Selection of gears was entirely by "feel", with no guide provided to assist operator. Fifteen inches of upper lever travel was required to shift from second to reverse gear. Fifteen inches of upper lever cross travel was required to shift from second to third gear. When shifting into fourth gear, the shift lever hit the steering gear. With cab door closed, the shift lever hit the door when shifting into second and reverse.

3. Clutch Pedal. The clutch pedal was hard to depress and awkward to reach, due to positioning ahead of steering wheel. In reaching for the clutch pedal, the operator's upper leg hit the steering wheel, causing discomfort as well as an awkward position. A hard-to-depress clutch pedal causes early operator fatigue and lessens production from the machine.

4. Clutch Pedal-Shift Lever. The relative position of clutch pedal to main shift lever made operation difficult. The gears most commonly used (reverse and second) required the operator to assume an awkward position in order to depress clutch pedal and shift gears. One operator complained of soreness and fatigue due to the awkwardness in shifting. The shift arrangement could be reversed in order, so as to relocate reverse and secone within normal reach of the operator. At lease one other grader using the same transmission is known to have made the change noted above.

5. Governor Control. The hand throttle is difficult to manipulate. While nothing more than a quarter turn ratchet mechanism, it appeared that the quarter turn was never being made in the right quadrant. While not of serious consequence, all other graders tested had more satisfactory throttle arrangements.

6. Emergendy Brake Lever. The latch control rod on the emergency brake lever fell out of the grip handle. This item was corrected by the factory representative but could have been of serious consequence if it had happened while parked on a grade.

It is the consensus of the observers that the controls on this grader showed lack of proper consideration on the part of the manufacturer to design, inspection, and workmanship.

XII. TURNING RADIUS

(1) - Turning radius determination was involved at first in definition. After the first several trials it was established that turning radius alone is meaningless unless road width required for the turn is known.

Accordingly, turning radius was established as the radius of the inside track of a complete turn. The distance between inside and outside tracks was taken as the required road width for the turn.

TABLE XIV

Turning Radius

	Rome	Max. Other	Min. Other
Turn. Radius - Right	27'-5"	27'-9"	21'-10"
" " - Left	26'-9"	29'-3"	22'-9"
Average Road Width	13'-4½"	13'-5½"	8'-1"

Even though wheelbase of the Rome 402 was 8" longer than the other graders tested, turning radius was on the average less than for other tandems.

The differences in road width required for the turn were negligible when compared with other tandems.

The test showed conclusively that none of the tandem graders tested could make a minimum radius turn on a 12-foot road bed.

(2)-Turn-Around. The results of the turn-around test are shown in Table XV.

TABLE XV

Turn-Around

Backups Required on	Rome	Max. Other	Min. Other
35-Foot Road	4	3	2
30-Foot Road	8	7	3

The Rome grader required more backups to turn in both the 30 and 35-foot sections than any of the other graders, even though turning radius was favorable. The excess overall dimension of 16" in length was just enough to require the extra pass.

XIII. BRAKE TEST

The service brakes were combination air and hydraulic. It was required that pressure be built up in the system to a predetermined pressure before grader could safely be operated. There was no safety locking device to set the brakes if air dropped to an ineffective pressure. No buzzer was provided in the cab to warn the operator of low air pressure. The small pressure gage provided to indicate air pressure was so located that it could not be readily seen by the operator when in a standing position.

The pipe and tubing used for the hydraulic lines over the tandems was not properly protected. Pipe runs accross tandem inspection hole plates had to be bent out of the way or disconnected when checking on interior of tandem housing. Rocks dropping from tires bent and partially cut one of the copper lines at the wheel drum. Refer to photograph - Fig. 18.

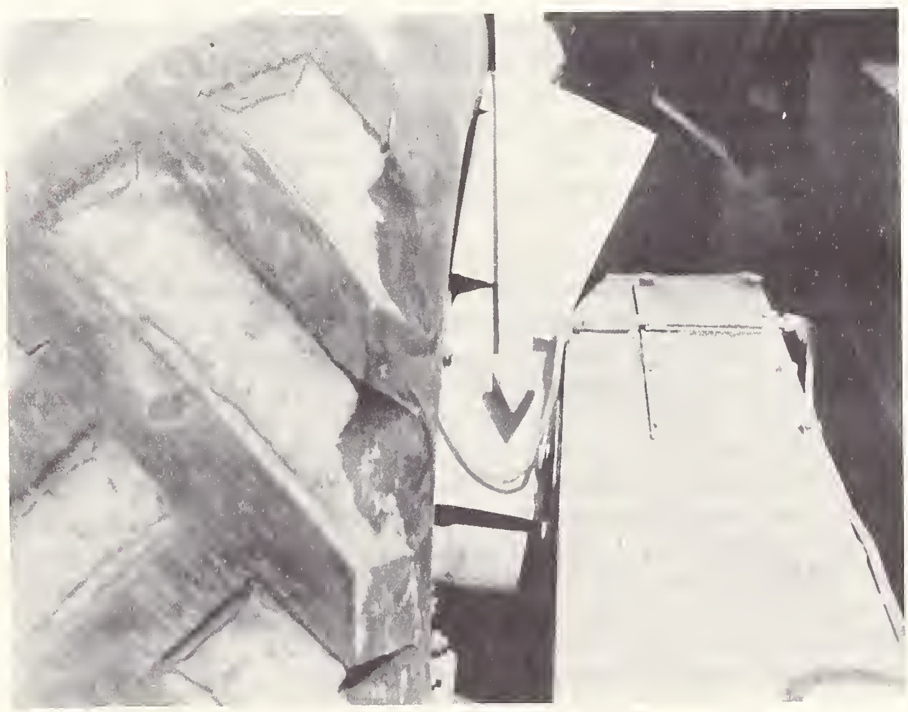


Fig. 18. Brake Lines on Tandem

The following table gives a comparison of the holding and stopping ability of service and parking brakes of the Rome 402 as compared with the maximum and minimum values found for other machines tested.

TABLE XVI

Brake Tests

	Rome	Other Machines Tested Maximum	Minimum
Serv. Brakes Uphill Hold	49%	49%	21%
Serv. " Downhill "	49%	49%	34%
Park. " Uphill "	$21\frac{1}{2}$%	49%	27%
Park. " Downhill "	15%	49%	32%
Stopping Dist. at 18 mph	32 ft.	38 ft.	15 ft.

California State Vehicle Code stopping distance at 18 mph - 30 ft.

The above table indicates that for holding power on steep grades at slow speeds, the service brakes of the Rome grader are entirely adequate. For quick stopping at high speeds, the service brakes could be classed as fair. Although the California State Vehicle Code for braking distances does not apply to motor patrol graders, the stopping distance requirements were used as a check on the ability of grader brakes. One tandem machine had brakes capable of stopping in 19 feet at 18 mph. One other tandem had stopping distances almost identical with the Rome. The fourth tandem with a stopping distance of 38 feet, had brakes that are considered inadequate.

The Table XVI further indicates that parking brakes of the Rome were the least effective of those on any unit tested. The parking brake was of the external band type and operated on the bull gear pinion shaft in the transmission. Minor adjustment could be made by shortening external linkage. Major adjustments, according to factory representative, required removal of engine and transmission case cover. Of the other machines tested, the listed minimum had the same parking brake system as the Rome 402. All other machines with a different type of parking brake, held on the maximum slopes. Failure to hold on normal slopes and necessity of major overhaul to adjust brake bands were reasons given by observers for stating that the parking brakes on this machine were inadequate for Forest Service use.

XIV. WALKING TEST

1. The highway walking test was divided into two sections. the first covered travel over asphalt paved highway with grades up to two percent. The second section covered travel over dirt highway with grades up to eight percent.

2. The truck trail walking test was divided into uphill and downhill sections. Grades varied from 14 percent uphill to 10 percent downhill.

Table XVII gives comparative speed data in miles per hour for each section of the highway and truck trail runs as well as overall mph for each distance.

TABLE XVII

Travel Speed (MPH)

Route	Distance	Rome	Other Graders Tested Maximum	Other Graders Tested Minimum
Paved highway	4.2 Mi.	20.90	24.60	15.80
Dirt highway	1.9 "	15.50	17.54	12.35
Total highway	6.1 "	18.90	19.94	14.50
Uphill truck trail	1.35 "	6.37	6.56	4.49
Downhill " "	2.3 "	10.63	16.24	9.13
Total truck trail	3.65 "	8.52	9.98	7.70

In the walking test the Rome 402 was not the fastest, but was above the average of the other machines tested.

1. In the first series of walking tests the machine did not perform to expectations. Quick response of steering ram made steering difficult at high speeds. Repeat tests were started with the restrictor valve partially closed but the operator felt that wheel response was entirely too sluggish. The final runs were made with the restrictor valve open, with the majority of steering being done by the leaning wheels. The speeds for these latter runs are recorded in Table XVII.

2. Speeds in the truck trail test were average and were obtained without difficulty. Steering was not noted as critical at the truck trail travel speeds.

XV. BREAKDOWNS

In terms of the definition of breakdowns as implied in "Description of the Tests" section of this report, it can be said that the machine did not fail. Had the tests continued over a longer period, and certainly if the machine had been used in service, breakdowns would have occured. Such items as loosening of brackets, chafing of hoses, play in ball studs, and the many items that required maintenance, referred to elsewhere in the report, were all sources of potential breakdown. The number of these items present in the Rome 402 was far in excess of the similar list of items for any of the other machines tested. Accordingly, although no time was lost due to breakdowns, it was the consensus of observers that the Rome 402 was the machine more prone to breakdown than any of the machines tested.

XVI. FINAL CHECK

On completion of the test the machine was returned to the "flat land" area. All complaints recorded were given a final check. In addition, a thorough check of the entire machine was made by shop mechanics. After inspection, several items, originally reported as possible sources of trouble, were found to have performed satisfactorily, and are not mentioned. Those which observers felt were not in accord with standard practice, were still possible sources of trouble, or obviously in need of correction, are listed in the following:

1. Hydraulic System.

A. The hydraulic system on the Rome operated at 750 pounds per square inch maximum pressure. In operating a control (or controls) any counteracting force in excess of 750 lbs./sq.in. would cause the by-pass valve to open. When by-pass pressure was reached on any one control, all other hydraulic controls were inoperative, including steering. All controls could be operated simultaneously if the cumulative pressure required for their function did not exceed by-pass setting, and provided the resistance to motion was approximately equal on all operations.

The other hydraulic controlled grader tested operated similarly to Rome when by-pass pressure was reached, but had the added advantages of functioning regardless of the individual resistances to motion, and operated at 900 lbs./sq.in.

Early in the test, and during the weighing of the machine, difficulty with establishing blade pressure was noted. It was not possible to lift the machine on the blade without difficulty. The hydraulic system by-pass valve was adjusted to increase the pressure. The controls functioned much better and with more power, but oil spurted from four of the hydraulic cylinders at the end caps. Pressure in the system at the new setting was checked at 900 lbs./sq.in. It was evident that these cylinders were not designed for pressures in excess of 750 lbs./sq.in. The by-pass was readjusted to the recommended setting before continuing tests, and was checked at this pressure several times during the test.

Toward the end of the test, operator complaints were specific with regard to the inability of the machine to lift the blade with a large blade load. It was necessary that the machine be stopped or reversed in order to release part of the load. A similar difficulty was reported with the leaning wheels. In a tight turn and in a bind, operator was not able to straighten the leaning wheels without stopping or reversing.

In the opinion of observers, the hydraulic system was operating at the critical pressure with no reserve for heavy work. It was anticipated that with machine wear trouble would be experienced with inability to adequately control the machine on truck trail operations.

B. Seven gallons of SAE 20 oil had to be added to the hydraulic system in one and one-half weeks of operation. The hydraulic pump showed a slight seepage, but it was evident that the bulk of oil loss was at the tank vent pipes. There was something obviously faulty with the method of venting which permitted oil to escape with the air. The oil, in turn, settled on the cab, on the tandem assembly, wheels and brake drums, contributing to a very unsightly appearance.

The two vent pipes protruded from the main hydraulic supply tank at rear of cab. They were not anchored, and depended on the street ell to hold. It was anticipated that vibration would cause early failure. Refer to photograph - Fig. 19.

C. The flexible hydraulic hoses leading from the front of the main grader frame to front of the circle drawbar, rubbed protruding pipe fittings. Both hoses were chafed and early failure could be expected unless corrected. Refer to photograph - Fig. 20.

Fig. 19. Vent Pipe Oil Leak

Fig. 20. Hose Chafing

D. The pipe which extended the full length of the scarifier cylinder was not anchored. One end of the pipe attached to lower end of cylinder with a street ell, and the other end attached to a flexible hydraulic hose line. The pipe was subject to vibration and swung free on the street ell. Pipe breakage or oil leaks could be anticipated at this point. The final check showed seepage at the ell. Refer to photograph - Fig. 21.

E. The hydraulic system was composed of several variable type pipes, valves, and fittings of questionable pressure capacity. Some fittings rated at 125 lbs./sq.in. were used in the 750 pound system. There was reason to believe these parts would not stand continued use at the pressures developed in operation.

F. Some of the hydraulic cylinder piston rods rusted and showed scratched surfaces, indicating no corrosion treatment of these parts. Deterioration of these surfaces would present future difficulty in preventing oil leakage, and cause rapid wear of oil seals or packings. Refer to photograph - Fig. 22.

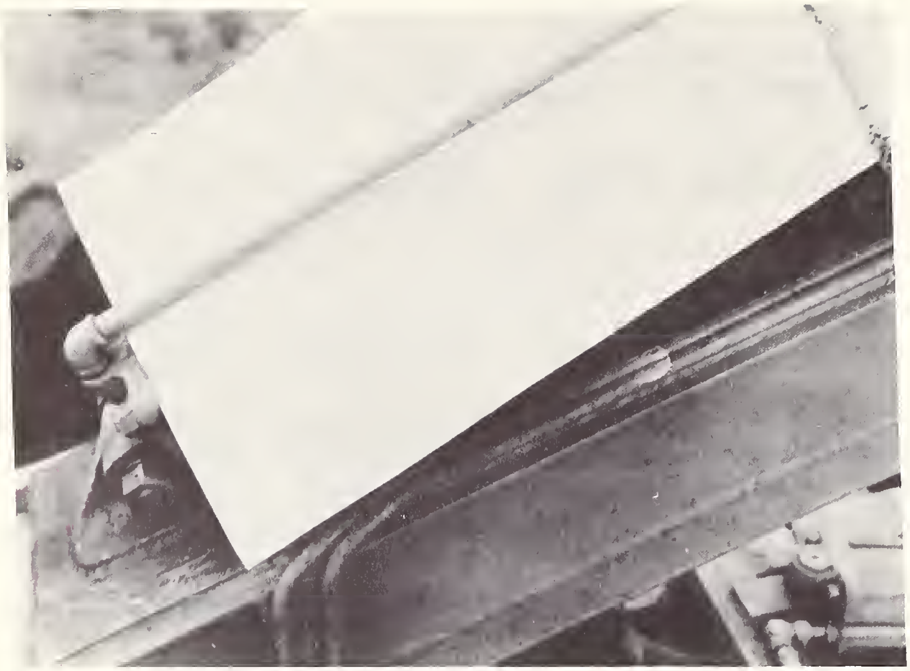


Fig. 21. Scarifier Cylinder Feed Line

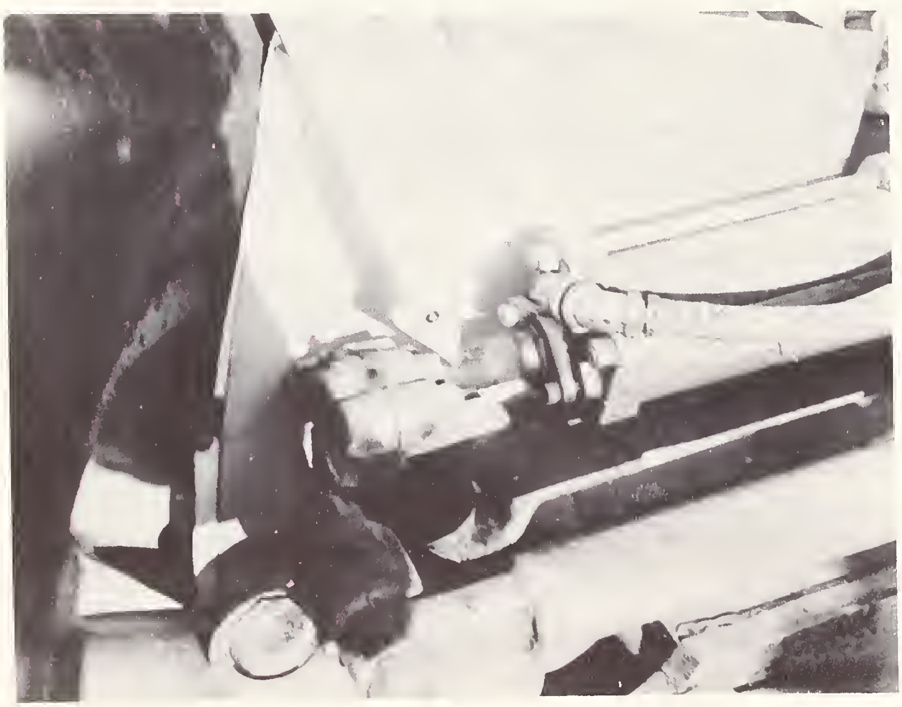


Fig. 22. Rust of Piston Rods

2. Cab

A. The left hand upper door glass was broken by striking the protruding molding on side of cab. Glass struck first instead of metal portion of door when doors were folded back in open position. A bumper block of some kind should be installed to cushion door and protect glass against striking. Refer to photograph - Fig. 23.

B. The door and other glasses were mounted in thin insulating tape, with no provision for absorbing twist and shock. Other graders were noted to have heavy rubber cushion mounting around glass to prevent breakage.

C. The windshield and rear cab glass could be opened only a few degrees. This limitation was undesirable when operators wished to open either glass for improved visibility in adverse conditions, or to obtain added ventilation in hot working conditions.

With the windshield partially opened, it was directly in the path of the lift ram and could be knocked off. See photograph - Fig. 24.

D. The seat cushion was fairly shallow in depth. An angle ledge in front of seat, which held cushion in position, projected high enough to "cut" operator's legs. Blocks of wood had to be installed behind seat to help overcome the discomfort.

E. No safety ledges were provided at floor board level of door openings. Other graders tested had these safety ledges to prevent operator's feet from slipping out of door if operating grader at tipped angle.

F. Difficulty was experienced in opening and closing cab doors. Clearances were such that unless the tandems were practically level doors would not swing.

G. Door latch retainer, used to hold door open, loosened in spite of repeated tightenings. This could have resulted in damage to door if it had released during operation.

H. No provisions were made for locking cab doors with a key.

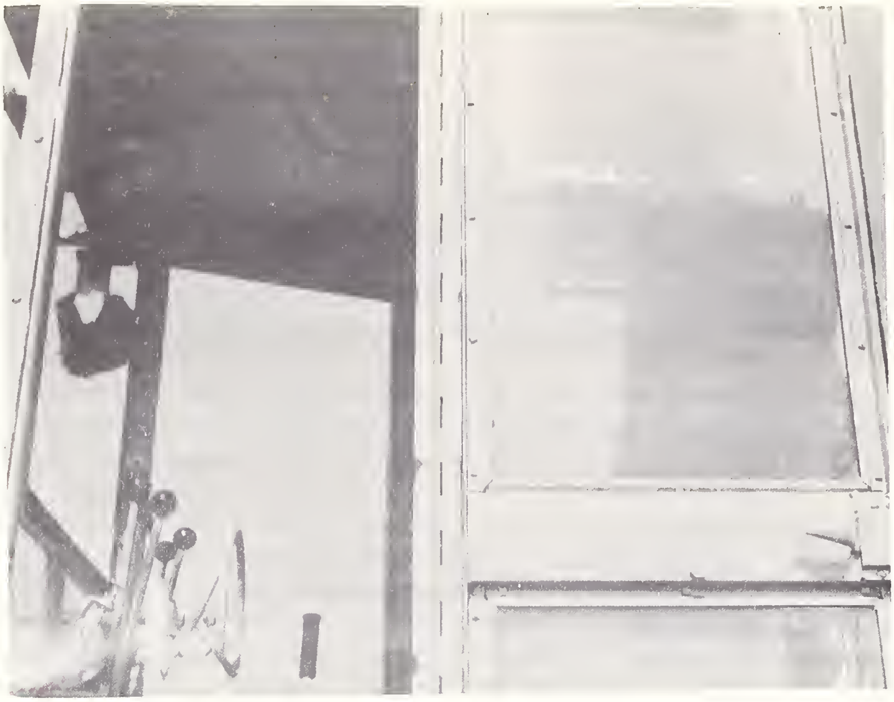


Fig. 23, Door Glass Break

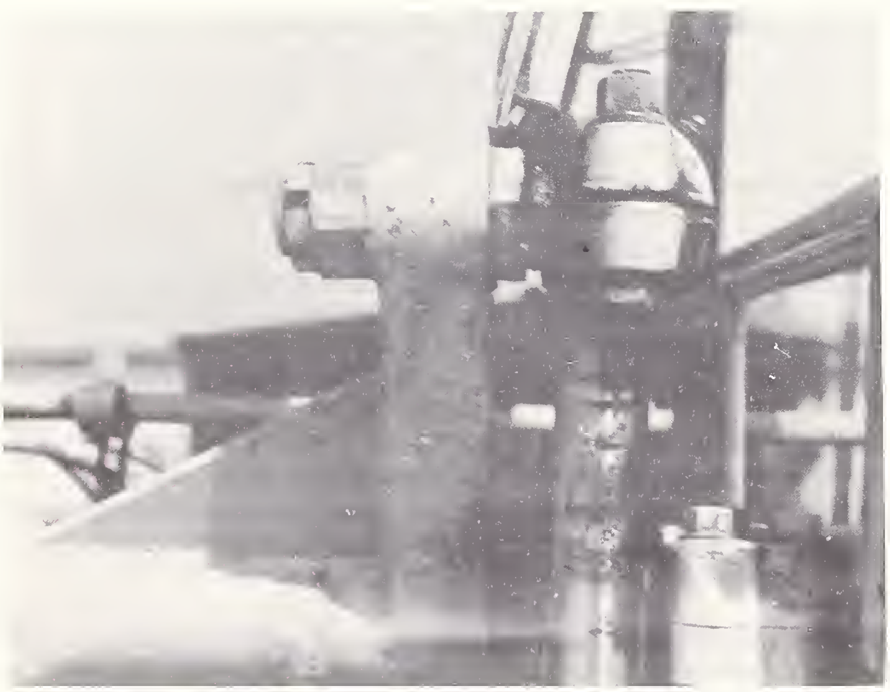


Fig. 24. Lift Ram Hits Windshield

3. <u>Clutch</u>

A. No clutch brake was provided. During the early stages of the test operators were noted to have difficulty in shifting gears, often clashing badly. Operator reaction, however, indicated that the condition was not abnormal. Several subsequent checks did not reveal any serious difficulty due to this cause. The four other graders tested in this class were equipped with clutch brakes.

Because of experience with previous graders with inadequate clutch brakes, this item was carefully checked by observers.

B. The clutch was noted to "smell" considerably on several occasions during the test. Clutch slippage, in the usual sense, however, was not noticeable. The only question raised by the observers was regarding the ability of the clutch to handle the high torque of the new engine. This could not be checked accurately and, accordingly, is noted as an item of record only.

4. <u>Linkage</u>

A. Both the circle lift shafts and lateral swing shafts were end-mounted at the dash in brackets secured by four bolts. The design was such that the full load and shock imposed on the moldboard was transferred to the four mounting bolts in each bracket. These brackets were noted to have shifted during the test and required repeated tightening. It was apparent that correction would be necessary at these points to assure trouble-free operation.

B. The lateral sideshift shaft front support bracket also shifted on its four mounting bolts during the test. These bolts were repeatedly tightened, but during the final check were found loose, apparently stretched from stress.

C. The lateral shaft assembly had 1/2 inch free longitudinal movement and the scarifier cross lift shaft was noted to have 3/4 inch free play for apparently no purpose. These items were not expected to cause any serious trouble but were evidence of excessive design tolerances.

D. A crack about 3/4 inch long appeared in the left lift shaft forward arm. Other hair-line cracks were visible beside and opposite the larger crack, indicating a partial failure of the arm. A 1/2 inch gusset plate welded to the arm at this point was bent. A weakness at this point was clearly indicated.

E. In extreme down position, the scarifier drawbar links hit the hydraulic hoses, fittings, and cylinder of the leaning wheel control when right front wheel was pivoted in "up" position. Although such a position would be unusual, it was possible to inadvertantly cause damage.

5. MISCELLANEOUS

A. Circle Teeth Wear. Considering the extent of use, the circle teeth appeared excessively worn, or otherwise distorted. Tooth contour had changed to some extent, and there was evidence of softness in tooth material. Pressure was apparently causing metal to "squeeze" and protrude at edges of the teeth.

B. Batteries. No fastenings were provided and batteries were free to bounce. Lateral shifting was restricted on three sides. The fourth side had a metal flange extending one inch upward from battery base. This was the only provision designed to prevent batteries from sliding or being jarred from position.

C. Steering Knuckle Plugs. Both expansion plugs on upper part of steering knuckle loosened and raised from their seated positions. Examination indicated that they were not correctly secured at the factory. Accepted practice is to "stake" the plugs to prevent dislodgment from greasing pressures. Loss of plugs would permit entry of dirt.

D. Oil Gage Line. Oil gage line from filter was not suported in a distance of $4\frac{1}{2}$ feet. Normal vibration could be expected to cause early failure.

E. Steering. Complaints regarding over-control of steering were prevalent throughout the test. In spite of all attempts to adjust the compensating globe valve in the line above steering cylinder control valve, satisfactory operation of the steering ram was not obtained. Toward conclusion of the test, the majority of steering, particularly, at higher speeds was being done with the leaning wheels.

F. Grease Leak. During the ditching operations a grease fitting on the hub of the right rear tandem was broken off. This allowed oil from the tandem to drain onto the ground. Repair was effected by removing a grease fitting from the scarifier lift link ball socket for installation in the tandem axle. The fittings, protruding as they did should have had some form of cap or protecting flange that would prevent damage.

DISCUSSION OF RESULTS

Field Tests

I. SLIDE REMOVAL

One fact which became apparent as field tests progressed was the lack of knowledge of various operators as to how much work a machine was capable of doing. In the case of the slide removal test, the normal operator's reaction was that the grader would be unable to do the task. As the test progressed the ability of machines improved as the operators gained more experience. Table XVIII gives comparative times required for machines to climb over the test slide.

TABLE XVIII

SLIDE REMOVAL

Time to	Rome	Other Machines Tested Maximum	Other Machines Tested Minimum
Climb slide	22 Min. 59 Sec.	50 Min.	15 Min. 57 Sec.

Time to climb slide was in direct relation to the method used. One machine, in attempting to climb over the slide, required over four times as long for the first trial as was required for the second attempt. The true test on the slide was not in the method of attack, number of passes, or time required, but in the appraisal of the maneuverability, traction, operator fatigue and blade stability. In time, Rome rated third of five machines. The machine with minimum time was able to accomplish the job by swinging the blade while heavily loaded. The machine requiring the longest time was the first of the graders to attempt the slide. It was made without benefit of previous experience or precedent. No rerun was made.

Climbing ability of the Rome in this test was considered adequate. Inability to swing blade under scarifier and difficulty with transmission controls hindered operations. It is of interest that the other machine which was considered to have a low weight horsepower ratio rated fourth in time to complete the test. Figures 25 and 26 show the slide before and after being worked on by the Rome.

Fig. 25. Slide - Before Test

Fig. 26. Slide - Completion of Test

II. IN-CURVE

In Fig. 5 is depicted a typical condition often encountered in forest road maintenance. Here not only a machine with a short turning radius, but one that would negotiate the curve with a minimum of road width was required. This was a difficult problem for any of the tandem graders. Lacking backup room, the first turn into the wash was difficult. The track width required for the Rome 402, after being maneuvered to make the entry, was 19'-11". This compared favorably to the average of 19'-8" for all of the other tandem machines tested. All tandems compared unfavorably with the four-wheel steer machine which required a road width of only 9'-7½". Data obtained from this test substantiated the conclusions of the "flat lands" turning radius runs.

III. GRADING OF DIPS

In the grading of dips, the Rome 402 had difficulty. The short total vertical blade travel, and the instability of the blade, made for poor operation. With the blade set for normal operation, the blade would clear the summit of the dip but did not have sufficient drop to properly grade the section in the runoff trough. Set for proper grading of the trough section, the blade could not be lifted sufficiently to clear the summit. Fig. 27 shows a shot of a dip before passage of the grader. The following photograph, Fig. 28, shows an after shot taken from the same position. Examination of the bank line where sluff was removed shows the erratic motion of the right side of the blade. Instead of cleaning out the trough section, the left side of the blade was unable to go even to the filled level, and actually deposited unwanted material. In the construction of dips, the same difficulty was encountered.

Subsequent field runs during road maintenance trials resulted in a five mile section being judged unacceptable for the same reasons.

Fig. 27. Dip - Before Maintenance

Fig. 28. Dip after Maintenance

IV. DITCHING

The site of this ditching operation, photograph Fig. 29, was in the same area as those worked on by other units. Adjacent strips immediately to right and left were worked on by other machines. The comparative time for the ditching test showed the Rome 402 to be 1 hour and 11 minutes slower than the next machine. The comparative table of ditching time, Table XIX, shows the overall spread between the Rome 402 and the other machines in the test.

TABLE XIX

DITCHING

		Other Machines Tested	
	Rome	Maximum	Minimum
Time to Construct Ditch	11 Hr.33 Min.	10 Hr.22 Min.	8 Hr.20 Min.

The most significant factor in the ditching operation was not the overall time, but rather the reasons for longer or shorter times. Considerable of the time lost during this operation could be attributed to drifting of the front wheels, side sliding of tandems, the fact that the shifting of gears was slower than for other machines, and operator fatigue. On at least one occasion, the operator indicated a desire to leave the machine because of personal abuse and difficulty in handling controls.

Fig. 29. Ditching Site Before Operation

Fig. 30. Ditching - During Operations

Fig. 31. Ditching - Completed

Figures 30 and 31 show the cut bank before and after attempts to bank slope to the required 3/4:1 slope. All attempts to do this with the machine in the ditch were futile and the final cut was made with the machine straddling the cut bank. At the completion of this test it was evident that conclusions regarding bank slope ability, made during the flat land tests were pertinent. A movie sequence taken during this operation clearly shows the difficulty experienced.

It is recognized that this ditching test was most severe and beyond the normal operations encountered or anticipated. It was in effect an accelerated aging test to determine the ability of the graders. It was the expressed opinion of observers, however, that two of the other units were given heavier punishment in this test than was the Rome. At times it appeared that excess flexing of the frame and blade assembly would cause failure. Regardless, credit must be given to the fact that during this test no structural failure occurred.

V. SCARIFYING

The work of scarifying the ditch surface was accomplished equally well by all machines. Teeth were broken because of the size of the imbedded rocks and operator abuse. The only casualty on the Rome, however, was a small chip off one tooth. This was accepted as normal for this type of operation and, accordingly, discounted.

VI. BANK SLOPING

Fig. 32. Rome Bank Slope

The Rome 402 grader was unable to bank slope to a standard acceptable to observers. Photograph, Fig. 32, shows one attempt at this operation. The slope of the bank was such that the tandems could not climb. On the approach to the out-curve in the foreground, the wheels rode as closely to the bank as possible. The tip of the blade barely touched at points. At the out-curve in the center of the picture, the blade was just able to do a partial smoothing job.

Fig. 33. Rome - Bank Slope

Fig. 34. Rome - Bank Slope

Photographs, Figs. 33 and 34, show other attempts to bank slope with the Rome grader. In both cases, in order to touch the bank, it was necessary for front wheel and rear tandems to climb the slope. In Fig. 34 the numerous wheel tracks are caused by second and third attempts to slope after adjusting the blade and linkage. Final sloping in this case was done when the tandems followed the highest tire track shown.

Failure of the machine to do bank sloping satisfactorily was attributed mainly to design of the entire blade, circle and linkage assemblies. Conditions anticipated from the "flat land" were proven in this test, particularly as regarding location of blade heel with respect to reference line. The movie sequence of this test clearly shows the position of the blade as well as the futile efforts of the operator to slope the bank.

Three of the other graders performed the bank sloping test satisfactorily, while the fourth could be rated only as passable.

VII. DRIFTING

The comparison Table XX for the drifting operation shows the overall spread of the machines tested. Rome 402 was fourth lowest in production. Again, the machine noted in the minimum column was the one that had the next lowest weight horsepower ratio.

TABLE XX

DRIFTING

	Rome	Other Machines Tested	
		Maximum	Minimum
Cu.yds./Min. Moved	1.00*	1.29	.97

*Two minutes lost in bank rock removal discounted in this computation.

Time lost in gear shifting was the main factor in the low rating. Operator difficulties ran a close second. Had it not been for these conditions, the Rome may have been in the upper bracket for performance.

Performance of the grader otherwise was normal with the exception of the repeated tendency of the blade to shift from level at the slightest obstruction. This difficulty, while not directly associated with production in this test, was obvious enough to attract attention.

VIII. HORIZONTAL MOVEMENT OF WINDROW

In this test, results were reduced to cu. yds. ft. side cast per minute. This factor was necessary for comparative purposes, since each machine moved a different amount of dirt varying distances to the side in varying periods of time. Table XXI gives the results.

TABLE XXI

WINDROW-CU. YDS.-FT./MIN.

	Grader			
Rome	A	B	C	D
96.5	107.0	149.0	145.2	85.5

In production, the Rome rated fourth. Classification of the completed test by observers rated it as a very poor job. The roadbed was gouged in several places, with other sections covered with loose and scattered material. Lack of blade control and side thrust were again the main factors in the conclusions. At times, side thrust on the front end under heavy loading, made it difficult for the operator to keep the wheels from climbing the windrow.

Photographs giving before and after views of the test site are shown in Fig. 35 and Fig. 36.

This particular run was the second trial at the windrow test. The first attempt was abandoned because of what appeared as a faulty selector valve. The factory representative effected repair of the sticking hand control valves and the grader was pronounced in suitable condition for test. The selector was ordered, however, but was never used.

Fig. 35. Windrow Before Test

Fig. 36. Windrow After Test

IX. SHAPING OF BERMS

The work in this test was relatively light and all units were rated equally. No significant features or failures were evident. Photograph, Fig. 37, shows a typical run during the test.

Fig. 37. Berm Shaping

X. HILL CLIMB

In this test all machines were able to climb the 49% grade in forward gear. In reverse the tandem machines were able to back up to the section of the hill on which the slope varied from 39% to 41%. At this point failure was due to lack of traction. The four-wheel-drive unit was the only one able to climb the hill in reverse.

XI. UPHILL GRADING

In the uphill grading test, the operator's complaint was that with a fully loaded blade and opened throttle, the rear wheels spun badly. Movie sequences show considerable slippage of wheels during this test. As a result, the finished operation left a series of waves where the operator in attempting to reduce slippage raised the blade to reduce the load. Photograph, Fig. 38, shows a view of the uphill grading test section. The material of the road bed is decomposed granite and grades averaged 15%. Comparative Table XXII gives the overall time required for the graders to operate over a 500 ft. stretch in this operation.

TABLE XXII

UPHILL GRADING

Time to do	Rome	Other Machines Tested Maximum	Other Machines Tested Minimum
Uphill Grading (500')	4 Min.6 Sec.	4 Min.	2 Min.50 Sec.

Fig. 38. Uphill Grading

XII. ROAD GRADING

The three-pass 500 foot road maintenance job was preliminary to the two mile maintenance run. Data taken was used only to assure observers of the ability of machine and operator to proceed with the longer test to follow. Numerous irregularities in the work indicated that a general tightening and adjustment of the machine was mandatory if successful operation was to be attained. Accordingly, at the conclusion of this run the machine was shut down and $2\frac{1}{2}$ hours were spent bleeding air from hydraulic system, removing shims in circle and ball cap assemblies, tightening brackets, bolts, linkage, and the other maintenance necessary to put the machine in the best operating condition possible. Observers considered the time required to prepare the machine for operation to be excessive.

XIII. ROAD MAINTENANCE

The two mile road maintenance run was the last of the field tests performed, and combined all of the operations, with the exception of bank sloping, normally required in road grading. This being the composite of the previous tests, observers were able to recheck various phases of operation previously noted, as well as to appraise the ability of the machine in shifting from one operation to another with minimum less of productive time.

In all of the grader trials, the field test of road maintenance did little more than reiterate the findings of the specialized tests. It did, however, transform conditions to language readily understandable to field men and, as such, served a very useful purpose.

The course selected for the Rome test was two miles long, had 40 interceptor drainage dips, one minimum radius curve (less than 35'), and had grades up to 20 percent. It consisted of decomposed granite, loam and some rock. Three passes were made averaging 1.52 miles per hour, or a total time for the test of 3 hours and 57 min. Speeds of other graders ranged from 1.47 to 1.91 miles per hour. A considerable portion of the variation in time could be directly attributed to operator difference in interpretation of the problem.

Many photographs were taken of the test in an effort to record the operation. These were studied during the preparation of the report. A few which were considered particularly pertinent are included as Figs. 39 to 43.

Photographs, Figs. 39 and 40, show before and after shots of an in-curve. When conditions were favorable, fairly level ground, no heavy rock or other obstructions such as dips, ruts or heavy slough, performance was entirely adequate.

Fig. 39. Inside Curve Before Grading

Fig. 40. Inside curve After Grading

Photograph, Fig. 41, shows an after shot of a piece of fine grading. In the lower left hand corner is shown a condition which was noted on many occasions. A distinct track caused by the dragging of a small rock shows. Study of the photograph indicates that the instant the blade hit the rock it was lifted and a hummock with a fairly large amount of small rocks was deposited. This was a very definite factor in the appraisal of fine grading operations. The cause in most cases was traced to slackness of linkage or air in the hydraulic system.

Fig. 41. Fine Grading

Photographs, Figs. 42 and 43, show before and after conditions of another typical section. The diagonal dirt ridge shown in Fig. 43 is an example of the result of blade instability and lack of control. Throughout the run similar conditions could be found, sometimes in the form of a ridge, other times as a gouge.

Fig. 42. Road Maintenance, Before

Fig. 43. Road Maintenance, After

In summarizing the two mile maintenance test, it was the considered opinion of field men and observers that the Rome had done a fair job. The operator reported that, as a result of tightening and servicing before the run, operation at first was fair but that toward the end of the job looseness was again noticeable. Lack of positive blade control, however, was very evident and was the chief cause for unsatisfactory reports.

Subsequent to the two mile run, and in accordance with previous plans, the grader was scheduled for a continued test along these same lines on a regular maintenance job. The operator assigned in this instance was a highly trained regular forest operator with considerable experience, but not as accomplished as the foreman who operated during the two mile test. Here the results were not as satisfactory. The engineer's report of one visit is quoted in the following:

> "This work was very poor. Blade controls did not work properly, resulting in a very poor surface. Uphill grading on 15 to 20% gradients was exceedingly poor. One five mile section inspected was unacceptable. The operator stated that he was having considerable trouble with the machine. This work had to be repeated."

This was the sentiment that prevailed in the field when the machine was shut down after completion of the authorized test.

CONCLUSIONS

Conclusions formulated and expressed are the result of experience with and test of the machine submitted for trial.

FLATLAND TESTS

1. Weight distribution for the Rome 402 Grader conformed to standard tandem practice.

2. Weight horsepower ratio was considered to be low.

3. Overall dimensions, while only slightly higher than average for tandems, contributed to difficulty in turn-around and bank sloping.

4. Speed variations, as allowed by rear axle and transmission ratios, were adequate.

5. Engine performance was superior to that of other units tested.

6. Blade rotation was difficult because of obstructions.

7. Bank sloping positions were impractical.

8. Power controlled blade side shift was less than for other graders tested.

9. Blade lift arm throw was less than for other graders tested.

10. Visibility was classed as fair.

11. Wheel lean, by commercial standards, was inadequate.

12. Ground clearance, though lowest of the tandems, was sufficient for test operations.

13. Daily maintenance required was in excess of all other graders tested.

14. Tires as furnished were adequate.

15. Rims, as furnished, were classed as not of a desirable type.

16. Fuel tank capacity was sufficient for a full day's operation.

17. Cab removal problem was comparable to that of other graders.

CONCLUSIONS (Cont'd)

18. Lights were satisfactory for forward illumination.

19. Operation of hydraulic hand controls was unsatisfactory.

20. Operation of gear shift levers was unsatisfactory.

21. Clutch pedal pressure was too severe for the average operator.

22. Relative position of clutch and main shift lever made operation awkward.

23. Throttle control as furnished did not function smoothly.

24. Turning radius was comparable to other tandems tested.

25. Service brakes were just passable.

26. Parking brake was poor.

27. Travel speeds were adequate.

28. Hydraulic systems, as designed, would not give trouble-free service.

29. Cab was not acceptable because of lack of normal facilities and consideration for safety and comfort of operator.

30. Design and construction of the linkage assemblies was the primary cause of blade difficulty.

31. On the basis of the many items noted to have given trouble, such as; excessive circle teeth wear, no battery hold-downs, chafed hydraulic hose, unsupported oil lines, rusting piston rods, bent scarifier links, unequal angle of wheel lean, rubbing cross stabilizer, loosening of linkage support brackets, spewing of oil from sump tank vents, loosened expansion knuckle plugs, and binding moldboard support brackets, it was concluded that selection of materials, completeness of design and construction detail had not been given sufficient consideration.

FIELD TESTS

1. The ability of the Rome to climb the slide was considered adequate but lack of blade maneuverability and slowness of transmission shift hindered the operation.

2. Performance of the Rome on the in-curve test compared favorably with other tandems.

3. The Rome 402 was unable to consistently grade or construct dips to the proper standard.

4. The results of the ditching test were unsatisfactory because of abuse to operator and inability of the machine to complete to specifications.

5. The scarifying test was accomplished satisfactorily.

6. The Rome 402 was unable to bank slope to an acceptable standard.

7. Production of the Rome in the drifting operation was acceptable.

8. In the wondrow test, the quantity of dirt moved was classed as fair but the quality of the finished job was not acceptable.

9. In berm shaping, the machine performed comparable to all other units tested.

10. In the hill climb, the performance of the Rome 402 was equal to all other tandems tested.

11. Loss of traction was the main cause for the poor quality of the finished job in the uphill grading test.

12. Maintenance required preparatory to the final road maintenance test was considered excessive.

13. The overall job on the two mile maintenance section, while interspersed with grievances previously noted, was rated as fair.

14. Continuous road grading to Forest Service standards cannot be accomplished by the Rome 402 grader without basic design changes which would eliminate excessive service and maintenance and permit performance equal to other graders in this class.

APPENDIX

RATING TABLE

As a check on the results of the motor grader test, a rating table was prepared to include several of the more common items generally considered when discussing patrol graders. The theory in the preparation of this table, if it can be so called, is based somewhat on the laws of random sampling.

Eight men - three engineers, one ranger, one mechanical draftsman-designer, two Depot Superintendents, and one Regional Office staff man - completed a rating table for the five graders, to include twenty-three items normally associated with equipment of this type. The items were listed only as headings with no detail to cover definition. Instructions for preparation requested that the rater draw his own conclusions as to the inference in the item, and rate accordingly. Rating was to be made by indicating the best as one, second best - two, etc., with machines of equal ability being rated by the same digit.

It was also recognized that all 23 of the rating items did not bear the same weights as to importance. Accordingly, each person preparing the questionnaire was requested to evaluate the relative importance of each and establish some weighting scale to cover.

A typical final form is shown with the items weighted, but without the ratings for the individual graders.

GRADER SCORING SHEET

	Weight Rating	A-C	Cat.	Rome	A-W	Adams
Blade Opr.	6					
Engine Starting	3					
Transmission Shift	5					
Opr. of Controls	6					
Breakdowns	4					
Availability of Parts	4					
Maint. Nec. to Opr.	1					
Walking Speeds	3					
Maneuverability of Machine	5					
Safety - Brakes	7					
Visibility	5					
Controls Shift	6					
Opr. Fatigue	5					
Opr. Training Necessary	1					
Dip Const. & Maint.	8					
Ditching	5					
Drifting	3					
Bank Sloping	2					
Scarifying	5					
Move Windrow	6					
Remove Slides	6					
Road Maint.	8					
Fine Grading	2					

The eight forms were converted to a final rating in percent and are tabulated below:

RATING TABLE

Individual	Grader A	Grader B	Grader C	Grader D	Rome
1	62.8	68.0	59.0	50.8	28.8
2	51.0	64.7	62.4	48.0	30.0
3	73.5	65.4	41.7	39.2	28.2
4	91.9	91.0	89.6	75.3	68.1
5	80.2	58.5	52.8	38.8	25.2
6	67.9	67.1	66.4	44.0	31.7
7	77.8	73.0	65.8	53.0	43.7
8	47.4	36.1	66.1	26.8	20.5
Average	69.1	65.5	63.0	47.6	34.5

It is significent that in all of the ratings, graders D and Rome held the positions of fourth and fifth respectively without transposition and by a substantial margin. Graders A and B changed from their average relative position three times, while Grader C changed only twice.

It is evident from the ratings that the consensus of the observers, as mentioned several times in the body of the report, can be substantiated, and is defined as:

Grader A	-	Most often	- First
" B	-	" "	- Second
" C	-	" "	- Third
" D	-	Definitely	- Fourth
" Rome	-	"	- Fifth

If further deduction from the table were permitted, and if the sample of eight men could be taken as a cross-section of the entire field, it could be concluded that Grader A is the most desirable for overall Forest Service work, with Graders B and C as acceptable alternates. Graders D and Rome would, because of their relative low rating, be classed as undesirable.

Finally, it could be said that even though Grader A is rated the highest, according to the table and comparison with the ultimate in graders for Forest Service work, it is only 69.1% effective.

AAA DETONATOR BRAKE TESTER

The electrically operated detonator brake tester, shown in photograph, Fig. A, is used to measure the effectiveness of equipment brakes. Mounted on the machine being tested, it is operated by two switches - the first controlled by an observer and the second mounted on the brake pedal.

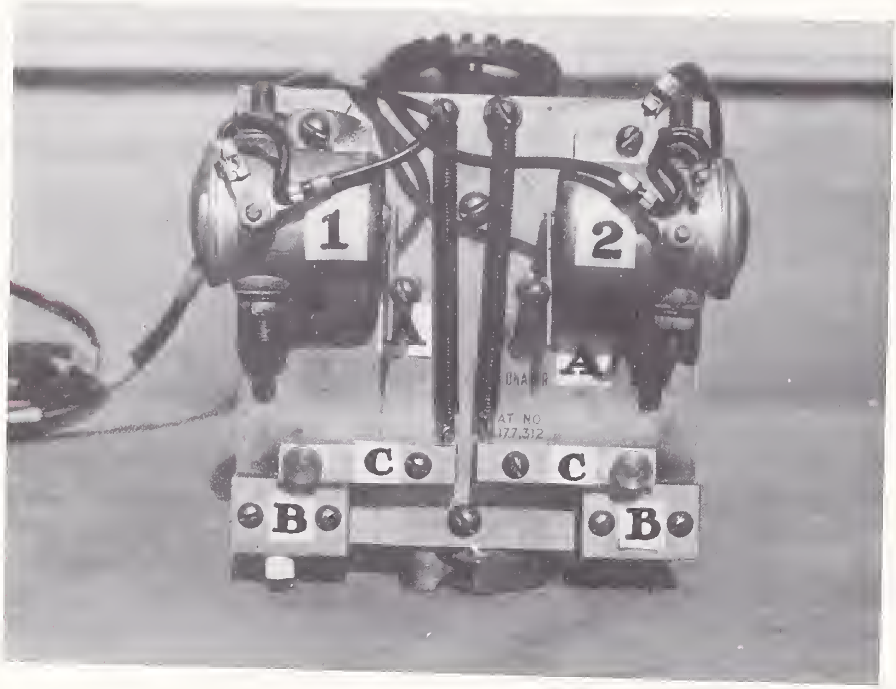


Fig. A. AAA Detonator Brake Tester

With the machine moving at the predetermined test speed, the observer operates the switch that releases solenoid 1 and allows its spring loaded hammer C to fire a blank cartridge in the block B. The force of the explosion expels chalk in the block and makes a mark on the pavement. On hearing the shot, the operator hits the brakes, causing the brake switch to release Solenoid 2, which fires a second piece of chalk to the pavement. When the machine comes to a complete stop a third chalk mark is made on the pavement directly under the detonator firing blocks.

The distance between the first and second shalk marks is measured and, since the speed of travel is known, can be converted into operator reaction time. The measurement between the second and third marks is the distance required to bring the vehicle to a stop at the given speed.

A complete description of the operation and use of this brake tester is available at the Arcadia Equipment Development Center, 701 N. Santa Anita Ave., Arcadia, California.